Chapter 8

Central Lake Michigan Coastal Ecological Landscape

Where to Find the Publication

The Ecological Landscapes of Wisconsin publication is available online, in CD format, and in limited quantities as a hard copy. Individual chapters are available for download in PDF format through the Wisconsin DNR website (**http://dnr.wi.gov/**, keyword "landscapes"). The introductory chapters (Part 1) and supporting materials (Part 3) should be downloaded along with individual ecological landscape chapters in Part 2 to aid in understanding and using the ecological landscape chapters. In addition to containing the full chapter of each ecological landscape, the website highlights key information such as the ecological landscape at a glance, Species of Greatest Conservation Need, natural community management opportunities, general management opportunities, and ecological landscape and Landtype Association maps (Appendix K of each ecological landscape chapter). These web pages are meant to be dynamic and were designed to work in close association with materials from the Wisconsin Wildlife Action Plan as well as with information on Wisconsin's natural communities from the Wisconsin Natural Heritage Inventory Program.

If you have a need for a CD or paper copy of this book, you may request one from Dreux Watermolen, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

Photos (L to R): American White Pelican, photo by Tom Schultz; clustered broomrape, photo by R.C. Moran; pygmy snaketail, photo by W.A. Smith, Wisconsin DNR; Long-tailed Duck, photo by Wolfgang Wander; Peregrine Falcon, photo by Laura Erickson.

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Cover Photos

Top left: *Caspian Tern (Wisconsin Endangered) occurs on lower Green Bay and along the Lake Michigan shore. Photo by Laura Erickson.*

Bottom left: *Beach and foredune, Point Beach State Forest, Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.*

Top right: *Wolf River floodplain. Photo by Eric Epstein, Wisconsin DNR.*

Bottom right: *Ridge-and-swale system, Point Beach State Forest, Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.*

Armund Bartz, WDNR

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Ryan O'Connor, WDNR

Central Lake Michigan Coastal Ecological Landscape at a Glance

Physical and Biotic Environment

Size

This ecological landscape encompasses 2,742 square miles (1,755,089 acres), representing 4.9% of the area of the state of Wisconsin.

Climate

The climate in the eastern part of this ecological landscape is moderated by its proximity to Lake Michigan, leading to warmer temperatures in the fall and early winter and somewhat cooler temperatures during spring and early summer that influence vegetation and other aspects of the ecology. Lake effect snow occurs in areas along the Lake Michigan coast during the winter. Mean growing season is 160 days (second longest in the state), mean annual temperature is 45.1°F, mean annual precipitation is 31.1 (second lowest in the state), and mean annual snowfall is 43.4 inches. Agriculture is the prevalent land use. Rainfall and growing degree days are conducive to supporting row crops, small grains, and pastures.

Bedrock

Bedrock that underlies this ecological landscape is mostly Silurian dolomite. It underlies all the counties along Lake Michigan, extending as far west as Lake Winnebago. It often appears as ridges or cliffs where surrounding bedrock has been eroded. Maquoketa shale occurs in a narrow strip along the Green Bay shoreline. West of Green Bay, the land is underlain by dolomitic rock with strata of limestone and shale. Farther inland, bands of sandstone lie roughly parallel to the Green Bay shore. An area in western Outagamie and eastern Shawano counties is deeply underlain by Precambrian granitic rocks. Where overlying glacial deposits are thin enough (e.g., in parts of the southern Door Peninsula), bedrock characteristics can directly affect the vegetation, especially where the substrate is strongly calcareous. Plant nutrients derived from limestone and dolomite have contributed to the development of unusual plant communities, and these in turn support rare or uncommon plants adapted to habitats containing high levels of calcium. Where dolomitic bedrock is close to the surface, runoff laden with sediments and pollutants can move quickly and over long distances through fractures in the rock and into the groundwater.

Geology and Landforms

Landforms are mostly glacial in origin, especially till plains and moraines, reworked and overlain in the western part by Glacial Lake Oshkosh. Beach ridges, terraces, and dunes formed near the shorelines of this glacial lake when sandy sediments were present. At other locations, boulder fields were formed when silts and clays were removed by wave action. Along Lake Michigan, coastal ridge-and-swale complexes, drowned river mouths (freshwater estuaries), and clay bluffs and ravines occur. The Niagara Escarpment is a prominent bedrock feature that runs along the east sides of lower Green Bay, Lake Winnebago, and the Fox River valley.

Soils

Most upland soils are reddish-brown calcareous loamy till or lacustrine deposits on moraines, till plains, and lake plains. Dominant soils are loamy or clayey with a silt loam surface with moderately slow permeability and high available water capacity.

Hydrology

Lake Michigan is a key ecological and socioeconomic feature. It influences the climate, created unique landforms, and is responsible in part for the presence and distribution of rare species. The shoreline constitutes a major flyway for migratory birds. Most of the major cities in this ecological landscape are located at the mouths of rivers entering Lake Michigan or Green Bay. Inland lakes are scarce, and all of them are small. The Embarrass River runs into the lower Wolf River, which runs into the Fox River, which drains Lake Winnebago and runs into Green Bay. The other major rivers here run directly into Lake Michigan and include the Ahnapee, Kewaunee, East Twin, West Twin, Manitowoc, Sheboygan, and Milwaukee.

Current Land Cover

Agriculture is the dominant land use here by area, and there are several medium-sized cities. Some large forested wetlands occur in both the eastern and western parts of the ecological landscape. The Wolf River bottoms are especially important in the west. Extensive marshes persist on the southwestern shore of Green Bay. The ridge-and-swale complex at Point Beach contains the largest area of Great Lakes coastal forest (with associated wetlands, dunes, and beaches) and constitutes an extremely important repository of regional biodiversity.

Socioeconomic Conditions

The counties included in this socioeconomic region are Waupaca, Outagamie, Brown, Kewaunee, Calumet, Manitowoc, Sheboygan, and Ozaukee.

Population

The population was 830,001 in 2010, 14.6% of the state total.

Population Density

212 persons per square mile

Per Capita Income

$36,555

Important Economic Sectors

The sectors producing the most jobs in 2007 were Manufacturing (non-wood) (14.5%), Tourism-related (11.1%), Government (9.5%), and Retail Trade (9.1%). Agriculture, industrial uses, and urbanization have the largest effect on the natural resources of this ecological landscape.

Public Ownership

Public lands in this ecological landscape include Point Beach State Forest, Harrington Beach and Kohler-Andrae State Parks, several state wildlife areas (including several units of Green Bay West Shores, C.D. Besadny, Collins Marsh, Brillion Marsh, and Navarino), state fishery areas, and state natural areas. University of Wisconsin-Green Bay owns Point Au Sable on lower Green Bay and land along lower Fischer Creek in Manitowoc County. Sheboygan Marsh is owned mostly by Sheboygan County but partly by the Wisconsin DNR. Other county ownerships include Maribel Caves (Manitowoc), Lily Lake (Brown), and at least part of the Cat Island chain in lower Green Bay (Brown). A map showing public land ownership (county, state, and federal) and private lands enrolled in the forest tax programs can be found in Appendix 8.K at the end of this chapter.

Other Notable Ownerships

Bay Beach Wildlife Sanctuary is owned by the City of Green Bay, and Woodland Dunes Nature Center is privately owned.

Great Lakes beach and dune complex. Progression from open beach to grassy foredune, shrub dune, xeric forest. Point Beach State Forest, Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.

Wolf River floodplain. Photo by Eric Epstein, Wisconsin DNR.

Considerations for Planning and Management

Fragmentation, especially of forested habitats, is severe in this ecological landscape. Many remnants of native vegetation are small and isolated, and there is not much public land. Where feasible, steps need to be taken to increase effective habitat area and minimize isolation by connecting scattered remnants, especially along shorelines and waterways. Additional stopover sites for migratory birds are needed along the Lake Michigan shoreline. Invasive plants are a major problem in both upland and wetland vegetation types. The lower Green Bay ecosystem continues to change rapidly; it seems unlikely that this area will stabilize in the immediate future. There is a need for an updated and expanded inventory of natural features here.

Because of the small amount of public land, local land trusts and other community-based conservation groups and private individuals will be among the most important conservation partners in this ecological landscape.

Management Opportunities

Lake Michigan forms the eastern boundary and is a dominant feature of the Central Lake Michigan Coastal Ecological Landscape. Most of the immediate shoreline is upland and has undergone extensive development to serve agricultural, residential, recreational, and urban-industrial uses. Many important protection and management opportunities are associated with characteristic Lake Michigan shoreline features such as beaches and dunes, ridge-and-swale complexes, alvar, ravines with native conifers, coastal forests and marshes, and migratory bird concentration areas.

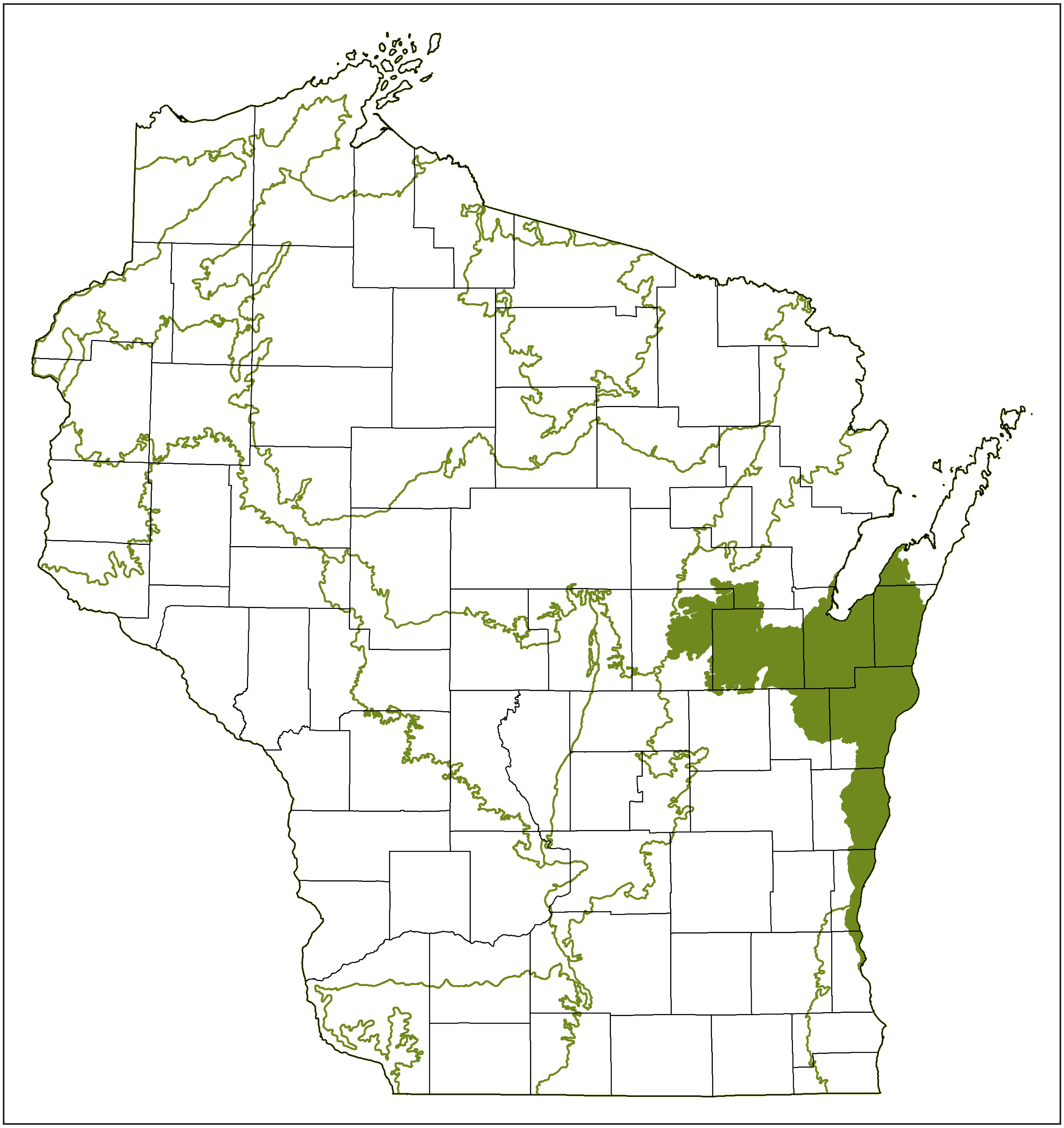
Shaky Lake. Photo by Eric Epstein, Wisconsin DNR.

Lower Green Bay and the mouth of the Fox River comprise a highly disturbed but rich ecosystem that includes the shallow waters of the lower bay, islands that support rookeries of fish-eating birds, and extensive coastal marshes and other wetland communities now concentrated west of the Fox River's mouth and along the bay's west shore. Important marsh complexes of lower Green Bay include Long Tail Point, Little Tail Point, Peats Lake and, east of the Fox River, Point Au Sable. All of these are heavily used by migratory and resident waterfowl and other birds. In recent decades, the marsh vegetation has undergone a drastic shift from diverse assemblages of native species to dominance by the highly invasive nonnative common reed, narrow-leaved cat-tail, and hybrid cat-tail. Protection of the remaining coastal marshes is a top priority, as is monitoring the impacts and effectiveness of the ongoing large-scale rehabilitation and restoration attempts.

A majority of the natural vegetation remaining in the western part of the ecological landscape is associated with the Wolf River floodplain. Significant acreages of lowland hardwood forest, shrub swamp, and marsh are present, along with smaller amounts of sedge meadow and mesic hardwood forest. The entire floodplain of the Wolf River merits protection as almost everything around it is now heavily developed. Similarly, the only extensive areas of natural vegetation in the eastern part of the ecological landscape away from the Lake Michigan-Green Bay shorelines are isolated but large wetlands in southern Door and Kewaunee counties and at several other locations to the south and west. Most of these wetlands are forested, with stands of swamp hardwoods, northern white-cedar, tamarack, and floodplain forest. Much of this land is in multiple private ownerships, with relatively few large single owners. There is a need to conduct field surveys and work with local residents and conservation groups to better document ecological values of these sites and identify those that offer the best opportunities for management and protection partnerships.

Lake Michigan is used heavily by waterfowl and other waterbirds, and its shoreline is important for migratory birds of many kinds, including waterfowl, loons, grebes, gulls, terns, shorebirds, raptors, and passerines. Providing or maintaining habitat for nesting, migrating, and wintering birds along and near Lake Michigan and Green Bay are important conservation goals. Management opportunities include maintaining and restoring the integrity of locations on Lake Michigan and its shoreline that receive heavy bird use as well as reforesting open locations along the shoreline for use as migratory stopover sites for land birds. There is also a need to provide stopover habitats at inland locations.

Among the miscellaneous features that are of at least local importance in the Central Lake Michigan Coastal Ecological Landscape are river and stream corridors, inland lakes, ephemeral ponds, remnant maple-beech forests, pine-oak forests, and surrogate grasslands. The last named features include some Great Lakes shoreline sites.



Central Lake Michigan Coastal Ecological Landscape

Thomas Meyer, WDNR

Central Lake Michigan Coastal Ecological Landscape

Introduction

This is one of 23 chapters that make up the Wisconsin DNR's publication *The Ecological Landscapes of Wisconsin: An Assessment of Ecological Resources and a Guide to Planning Sustainable Management.* This book was developed by the Wisconsin DNR's Ecosystem Management Planning Team and identifies the best areas of the state to manage for natural communities, key habitats, aquatic features, native plants, and native animals from an ecological perspective. It also identifies and prioritizes Wisconsin's most ecologically important resources from a global perspective. In addition, the book highlights socioeconomic activities that are compatible with sustaining important ecological features in each of Wisconsin's 16 ecological landscapes.

The book is divided into three parts. Part 1, "Introductory Material," includes seven chapters describing the basic principles of ecosystem and landscape-scale management and how to use them in land and water management planning; statewide assessments of seven major natural community groups in the state; a comparison of the ecological and socioeconomic characteristics among the ecological landscapes; a discussion of the changes and trends in Wisconsin ecosystems over time; identification of major current and emerging issues; and identification of the most significant ecological opportunities and the best places to manage important natural resources in the state. Part 1 also contains a chapter describing the natural communities, aquatic features, and selected habitats of Wisconsin. Part 2, "Ecological Landscape Analyses," of which this chapter is part, provides a detailed assessment of the ecological and socioeconomic conditions for each of the 16 individual ecological landscapes. These chapters identify important considerations when planning management actions in a given ecological landscape and suggest management opportunities that are compatible with the ecology of the ecological landscape. Part 3, "Supporting Materials," includes appendices, a glossary, literature cited, recommended readings, and acknowledgments that apply to the entire book.

This publication is meant as a tool for applying the principles of ecosystem management (see Chapter 1, "Principles of Ecosystem and Landscape-scale Management"). We hope it will help users better understand the ecology of the different regions of the state and help identify management that will sustain all of Wisconsin's species and natural communities while meeting the expectations, needs, and desires of our public and private partners. The book should provide valuable tools for planning at different ***scales***, including master planning for Wisconsin DNR-managed lands, as well as assist in project selection and prioritization.

Many sources of data were used to assess the ecological and socioeconomic conditions within each ecological landscape. Appendix C, "Data Sources Used in the Book" (in Part 3, "Supporting Materials"), describes the methodologies used as well as the relative strengths and limitations of each data source for our analyses. Information is summarized by ecological landscape except for socioeconomic data. Most economic and demographic data are available only on a political unit basis, generally with counties as the smallest unit, so socioeconomic information is presented using county aggregations that approximate ecological landscapes unless specifically noted otherwise.

Rare, declining, or vulnerable species and natural community types are often highlighted in these chapters and are given particular attention when Wisconsin does or could contribute significantly to maintaining their regional or global abundance. These species are often associated with relatively intact natural communities and aquatic features, but they are sometimes associated with cultural features such as old fields, abandoned mines, or dredge spoil islands. Ecological landscapes where these species or community types are either most abundant or where they might be most successfully restored are noted. In some cases, specific sites or properties within an ecological landscape are also identified.

Although rare species are often discussed throughout the book, "keeping common species common" is also an important

Terms highlighted in green are found in the glossary in Part 3 of the book, "Supporting Materials." Naming conventions are described in Part 1 in the Introduction to the book. Data used and limitation of the data can be found in Appendix C, "Data Sources Used in the Book," in Part 3.

consideration for land and water managers, especially when Wisconsin supports a large proportion of a species' regional or global population or if a species is socially important. Our hope is that this publication will assist with the regional, statewide, and landscape-level management planning needed to ensure that most, if not all, native species, important habitats, and community types will be sustained over time.

Consideration of different scales is an important part of ecosystem management. The 16 ecological landscape chapters present management opportunities within a context of ecological functions, natural community types, specific habitats, important ecological processes, localized environmental settings, or even specific populations. We encourage managers and planners to include these along with broader landscape-scale considerations to help ensure that all natural community types, ***critical habitats***, and aquatic features, as well as the fauna and flora that use and depend upon them, are sustained collectively across the state, region, and globe. (See Chapter 1, "Principles of Ecosystem and Landscape-scale Management," for more information.)

Locations are important to consider since it is not possible to manage for all species or community types within any given ecological landscape. Some ecological landscapes are better suited to manage for particular community types and groups of species than others or may afford management opportunities that cannot be effectively replicated elsewhere. This publication presents management opportunities for all 16 ecological landscapes that are, collectively, designed to sustain as many species and community types as possible within the state, with an emphasis on those especially well represented in Wisconsin.

This document provides useful information for making management and planning decisions from a landscape-scale and long-term perspective. In addition, it offers suggestions for choosing which resources might be especially appropriate to maintain, emphasize, or restore within each ecological landscape. The next step is to use this information to develop landscape-scale plans for areas of the state (e.g., ecological landscapes) using a statewide and regional perspective that can be implemented by field resource managers and others. These landscape-scale plans could be developed by Wisconsin DNR staff in cooperation with other agencies and nongovernmental organizations (NGOs) that share common management goals. Chapter 1, "Principles of Ecosystem and Landscape-scale Management," in Part 1 contains a section entitled "Property-level Approach to Ecosystem Management" that suggests how to apply this information to an individual property.

How to Use This Chapter

The organization of ecological landscape chapters is designed to allow readers quick access to specific topics. You will find some information repeated in more than one section, since our intent is for each section to stand alone, allowing the reader to quickly find information without having to read the chapter from cover to cover. The text is divided into the following major sections, each with numerous subsections:

- Environment and Ecology
- Management Opportunities for Important Ecological Features
- Socioeconomic Characteristics

The "Environment and Ecology" and "Socioeconomic Characteristics" sections describe the past and present resources found in the ecological landscape and how they have been used. The "Management Opportunities for Important Ecological Features" section emphasizes the ecological significance of features occurring in the ecological landscape from local, regional, and global perspectives as well as management opportunities, needs, and actions to ensure that these resources are enhanced or sustained. A statewide treatment of integrated ecological and socioeconomic opportunities can be found in Chapter 6, "Wisconsin's Ecological Features and Opportunities for Management."

Summary sections provide quick access to important information for select topics. "Central Lake Michigan Coastal Ecological Landscape at a Glance" provides important statistics about and characteristics of the ecological landscape as well as management opportunities and considerations for planning or managing resources. "General Description and Overview" gives a brief narrative summary of the resources in an ecological landscape. Detailed discussions for each of these topics follow in the text. Boxed text provides quick access to important information for certain topics ("Significant Flora," "Significant Fauna," and "Management Opportunities").

Coordination with Other Land and Water Management Plans

Coordinating objectives from different plans and consolidating monetary and human resources from different programs, where appropriate and feasible, should provide the most efficient, informed, and effective management in each ecological landscape. Several land and water management plans dovetail well with *The Ecological Landscapes of Wisconsin*, including the Wisconsin Wildlife Action Plan; the Fish, Wildlife, and Habitat Management Plan; the Wisconsin Bird Conservation Initiative's (WBCI) All-Bird Conservation Plan and Important Bird Areas program; and the *Wisconsin Land Legacy Report*. Each of these plans addresses natural resources and provides management objectives using ecological landscapes as a framework. Wisconsin DNR ***basin*** plans focus on the aquatic resources of water basins and watersheds but also include land management recommendations referencing ecological landscapes. Each of these plans was prepared for different reasons and has a unique focus, but they overlap in many areas. The ecological management opportunities provided in this book are consistent with the objectives provided in many of these plans. A more thorough discussion of coordinating land and water management plans is provided in Chapter 1, "Principles of Ecosystem and Landscape-scale Management."

General Description and Overview

The Central Lake Michigan Coastal Ecological Landscape stretches from southern Door County west across Green Bay to the Wolf River drainage, then southward in a narrowing strip along the Lake Michigan shore to central Milwaukee County. Owing to the influence of Lake Michigan, in the eastern part of this ecological landscape summers are generally cooler, winters warmer, and precipitation levels greater than at locations farther inland. Dolomites and shales underlie the glacial deposits that blanket virtually all of the Central Lake Michigan Coastal Ecological Landscape. The dolomite ***Niagara Escarpment*** is the major bedrock feature, running through the entire ecological landscape in an arc from northeast to southwest. Series of dolomite cliffs provide critical habitat for rare terrestrial snails, bats, and specialized plants. The primary glacial landforms are ground moraine, outwash, and lakeplain. The topography is generally rolling where the surface is underlain by ground moraine, variable over areas of outwash, and nearly level where lacustrine deposits are present. Important soils include clays, loams, sands, and gravels. Certain landforms, such as sand spits, clay bluffs, beach and dune complexes, and ridge-and-swale systems are associated only with the shorelines of Lake Michigan and Green Bay.

Historically, most of this ecological landscape was vegetated with mesic hardwood forest composed primarily of sugar maple (*Acer saccharum)*, American basswood (*Tilia Americana)*, and American beech (*Fagus grandifolia)*. Eastern hemlock (*Tsuga canadensis)* and eastern white pine (*Pinus strobus)* were locally important, but eastern hemlock was generally restricted to cool moist sites near Lake Michigan. Areas of poorly drained glacial lakeplain supported wet forests of tamarack (*Larix laricina)*, northern white-cedar (*Thuja occidentalis*), black ash (*Fraxinus nigra)*, red maple (*Acer rubrum)*, and elms (*Ulmus* spp.*)*, while the Wolf and Embarrass rivers flowed through extensive floodplain forests of silver maple (*Acer saccharinum)*, green ash (*Fraxinus pennsylvanica)*, and swamp white oak (*Quercus bicolor)*. Emergent marshes and wet meadows were common in and adjacent to lower Green Bay, while Lake Michigan shoreline areas featured beaches, dunes, interdunal wetlands, marshes, clay bluffs and ravines, and highly diverse ridge-and-swale vegetation. Small patches of prairie and oak savanna were present, mostly in the southwestern portion of this ecological landscape.

Most of the upland forest has been removed over the past 150 years as the land was converted to agricultural, residential, and industrial uses. Today approximately 84% of this ecological landscape is nonforested compared to 96% forested historically. The remaining forest consists mainly of mesic maple-basswood or maple-beech types or lowland hardwoods composed of red and silver maples, ashes (*Fraxinus* spp), and elms. Fragmentation of upland habitats is severe throughout this ecological landscape. Invasive species have become a major concern in both terrestrial and aquatic habitats. Reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), garlic mustard (*Alliaria petiolata*), nonnative Eurasian buckthorns (*Rhamnus* spp.), Eurasian honeysuckles (*Lonicera tatarica, Lonicera morrowii,* and *Lonicera* x *bella*), and common carp (*Cyprinus carpio*) are especially troublesome. Significant wetlands are still present, but most have been affected to varying degrees by hydrological disruption, pollution, sedimentation, and the encroachment of invasive species. Large acreages of marsh in lower Green Bay have been filled to accommodate industrialization and urban development.

Agricultural landscape, Winnebago County, north of Rat River. Photo by Eric Epstein, Wisconsin DNR.

The biota is especially noteworthy for the rare regional endemic plants and animals associated with Lake Michigan shoreline habitats and the highly specialized animals inhabiting the Niagara Escarpment. The coastal areas annually host significant concentrations of migratory birds, especially during the spring and fall migration periods. The waters of Lake Michigan and Green Bay and the Wolf-Embarrass River corridors provide seasonally critical habitat for numerous animals. Inland lakes are uncommon, and most of them have been at least partially developed.

The total land area for the Central Lake Michigan Coastal Ecological Landscape is approximately 1.8 million acres, of which only 16% is classified as ***timberland***. Public lands make up less than 3% of this ecological landscape but include several notable and heavily visited State properties such as Harrington Beach and Kohler-Andrae State Parks, Point Beach State Forest, and Collins Marsh State Wildlife Area.

Agriculturally, the Central Lake Michigan Coastal counties are very productive, with the third highest percentage of farmland acreage, the highest milk production per acre, and the second highest per acre market value of agricultural products among all of the ecological landscapes of Wisconsin. (Economic data are often not available by ecological landscape, so we have used "county approximations." See the

"Socioeconomic Characteristics" section of this chapter.) In terms of water usage, over 92% of water used in the Central Lake Michigan Coastal counties is used for thermoelectric power generation. Manitowoc County alone accounts for 45% of water usage, almost entirely for this purpose.

Compared to other ecological landscape county approximations, the Central Lake Michigan Coastal counties are very densely populated, with a young, well-educated, and racially diverse population. The population density of the region (212 persons per square mile) is about twice that of the state as a whole (105 persons per square mile). Among all ecological landscape county approximations, the Central Lake Michigan Coastal counties have the second highest percentage of people under 18 and a below-average proportion of elderly (over 65). In addition, the Central Lake Michigan Coastal counties are less racially diverse than the state as a whole. They also have a slightly higher percentage of high school graduates.

Economically, the region is relatively prosperous. The Central Lake Michigan Coastal counties have higher per capita income, lower average wages, and lower rates of unemployment and adult and child poverty than the state average. The economy depends heavily on manufacturing and much less on the government sector than some other regions. Both the agriculture and service sectors have below-average representation in the job market. Agriculture and urbanization have the largest effect on the natural resources of the ecological landscape.

Environment and Ecology

Physical Environment

Size

The Central Lake Michigan Coastal Ecological Landscape encompasses 2,742 square miles (1,755,089 acres), representing 4.9% of the area of the state of Wisconsin.

Climate

Climate data were analyzed from 10 weather stations within the Central Lake Michigan Coastal Ecological Landscape (Brillion, Appleton, Green Bay, Kewaunee, Manitowoc, New London, Plymouth, Port Washington, Sheboygan, and Two Rivers; WSCO 2011). This ecological landscape has a continental climate, with cold winters and warm summers similar to other southern ecological landscapes (Central Sands Hills, Central Sand Plains, Southeast Glacial Plains, Southern Lake Michigan Coastal, Southwest Savanna, Western Coulees and Ridges, and Western Prairie). The southern ecological landscapes in Wisconsin generally tend to have longer growing seasons, warmer summers, warmer winters, and more precipitation than the ecological landscapes farther to the north. Ecological landscapes adjacent to the Great Lakes generally tend to have warmer winters, cooler summers, and higher precipitation, especially snow. The climate in this ecological landscape is moderated by its proximity to Lake Michigan, leading to warmer temperatures in the fall and early winter, and slightly cooler temperatures during spring and early summer (although this effect can be dramatic on the immediate shoreline). This results in more growing degree days here than ecological landscapes farther inland in southern Wisconsin. Although this ecological landscape borders Lake Michigan, increased precipitation and snowfall were not reported by the weather stations cited above. A narrow zone along the Lake Michigan coast can get substantial "lake effect" snows under certain conditions during the winter.

The average growing season is the second longest of all ecological landscapes in Wisconsin, with a mean of 160 days (base 32°F). There is some variation of growing degree days within the ecological landscape (from 145 to 184 days) with weather stations farther away from Lake Michigan and farther north having fewer growing degree days.

The mean annual temperature is 45.1°F, the same as other ecological landscapes in southern Wisconsin. Mean annual temperature did not differ at weather stations inland or on the Lake Michigan shore within this ecological landscape, despite warmer temperatures in winter and cooler temperatures in summer along Lake Michigan. Average January minimum temperature is 0°F, almost 4 degrees cooler than other ecological landscapes in southern Wisconsin. The average August maximum temperature is 80.3°F, almost one degree cooler than other southern Wisconsin ecological landscapes. Despite the similarity in mean temperatures, growing degree days are longer in this ecological landscape, affecting the vegetation that occurs here.

Mean annual precipitation is 31.1 (29–36) inches, the second lowest level of precipitation compared with other ecological landscapes in the state. Only the Northwest Lowlands Ecological Landscape has a lower amount of precipitation (30.6 inches). Comparison between data from weather stations inland and on the shore of Lake Michigan in this ecological landscape showed slightly more precipitation inland (0.8 inch) than on the lakeshore, contrary to what was expected. However, the weather station at Plymouth was at the extreme high end of precipitation measured (almost 6 inches more precipitation than the average of other weather stations here). Observer differences and optional methods employed at some volunteer weather stations resulted in high variability among weather stations (Kunkel et al. 2007). If the Plymouth weather station was excluded from this analysis, there was slightly more precipitation along the lakeshore.

Mean annual snowfall is 43.4 inches, ranging from 22 inches to 61.4 inches, slightly more (1.5 inches) than other ecological landscapes in southern Wisconsin. Comparison of data from weather stations inland and on the shore of Lake Michigan in this ecological landscape showed more snowfall inland (8.8 inches) than on the lakeshore. The weather station at Plymouth was at the extreme high end of the snowfall measured (almost 18 inches more snowfall in Plymouth compared to the average of other weather stations). The Manitowoc weather station was at the extreme low end of snowfall measured (over 21 inches less snowfall than the average of other weather stations). As mentioned above, observer differences and optional methods of weather data collection caused high variability among volunteer weather stations (Kunkel et al. 2007). If the data from the Plymouth and Manitowoc weather stations are removed from the analysis, snowfall was similar inland and along the lakeshore. Part of the observed variability in snowfall may be due to observer differences and optional methods employed at some volunteer weather stations as well as other unknown factors.

The warmer temperatures in the fall and early winter and slightly cooler temperatures during spring and early summer influence the vegetation and ecology in the Central Lake Michigan Coastal Ecological Landscape. There is adequate rainfall and growing degree days to support agricultural row crops, small grains, hay, and pastures, which are prevalent in this ecological landscape.

Bedrock Geology

The Central Lake Michigan Coastal Ecological Landscape is underlain by a variety of sedimentary and igneous rocks of Devonian, Silurian, Ordovician, Cambrian, and Proterozoic origin. (Nomenclature used herein is according to Wisconsin Geological and Natural History Survey Open-File Report *Bedrock Stratigraphic Units in Wisconsin;* WGNHS 2006.) Bedrock beneath most of the ecological landscape is Silurian Niagara dolomite (this rock forms the Niagara Escarpment, a ridge that becomes a prominent surface feature on the east side of the Fox River valley and along the east side of Green Bay). Niagara dolomite underlies all the counties along Lake Michigan, extending as far west as Lake Winnebago. It is the most resistant of the Paleozoic rocks in Wisconsin, so it often appears as ridges or cliffs where surrounding bedrock has been eroded (Schultz 2004). Maquoketa shale is the uppermost bedrock along a narrow strip of the Green Bay shoreline. A small area at the southern tip of the ecological landscape is underlain by the youngest bedrock in Wisconsin, a Devonian deposit of dolomite and shale. West of Green Bay, the land is underlain by the Sinnipee Group, a dolomitic rock with strata of limestone and shale. Farther inland, bands of St. Peter Formation sandstone, Prairie du Chien dolomite, and Cambrian sandstone lie roughly parallel to the shore (Mudrey et al. 1981). An area in western Outagamie and eastern Shawano counties is deeply underlain by Precambrian granitic rocks (Brown 2005). See the map "Bedrock Geology of Wisconsin" in Appendix G, "Statewide Maps," in Part 3. Glacial sediment in most of the ecological landscape is more than 50 feet deep over bedrock, with the thickest deposits near the western boundary. In a few places, notably the small portion of the ecological landscape that lies in Door County, glacial deposits are thin enough that bedrock characteristics directly affect vegetation. Plant nutrients from limestone and dolomite have contributed to the development of unusual plant communities, which support species associated with calcareous habitats. Fractures in the dolomite bedrock can have a strong influence on hydrology and water quality where the rock is close to the surface (Sherrill 1978, USGS 2007). About a quarter of the ecological landscape has sediment deposits less than 50 feet thick, and these areas have the greatest potential for groundwater contamination because runoff can enter bedrock fissures and readily make its way into aquifers (Hooyer et al. 2008).

The Niagara Escarpment is the most significant bedrock feature in the ecological landscape. It is a 650-mile-long ***cuesta*** (bedrock ridge) of fossiliferous dolomitic limestone. Dolomite of the Niagara Escarpment was formed from accumulated sediments of an ancient sea around 415 to 430 million years ago, during the Silurian Period of the Paleozoic Era. The cuesta passes through northern Illinois south and west of Lake Michigan, runs along the western and northern shores of Lake Michigan in Wisconsin and Upper Michigan, then trends southeast under Lake Huron to Ontario. In New York, it forms the dramatic Niagara Falls, and continues eastward to the area near Rochester. Other parts of this bedrock deposit, in Iowa, northern Illinois, and Indiana, are deeply buried by glacial deposits (Schultz 2004). Outcrops are primarily located along the western edge of the cuesta, as the eastern edge is tipped downward toward the Lake Michigan basin. Inland exposures of bedrock pavement are located in Kewaunee County, primarily near the north end of Lipsky Swamp and extending north through Door County (Clayton 2004). The escarpment forms a high ridge along the Green Bay side of Door County, but from Sturgeon Bay southwest, it is divided into two lower ridges and is more dissected; thus, dolomite bluffs are more scarce and are of relatively low elevation in this ecological landscape (Schneider 1993a). The escarpment trends southwest from the city of Green Bay to High Cliff State Park on Lake Winnebago, where it crosses into the Southeast Glacial Plains Ecological Landscape. It continues southward through the town of Oakfield, forms the eastern edge of Horicon Marsh, and then becomes more deeply buried by glacial sediments. Niagara Escarpment outcrops are associated with many rare plants, land snails, and globally rare community types. The dolomite contains fossils of marine organisms, and fossilized coral reefs have been found, particularly in the Milwaukee-to-Racine area (Dott and Attig 2004). A cluster of hills near Dyckesville in Kewaunee County (Figure 8.1) are likely formed on Silurian reefs (Clayton 2004).

Dolomite is a sedimentary rock that originated as mud, with horizontal bedding-plane joints that developed between layers of sediment as they were deposited from oceans and vertical joints that formed when ancient seas retreated and the mud dried and cracked open in fissures. The dolomite is considered karstic where these joints and fissures have been enlarged by percolating surface water. Karst is most common on the Door County Peninsula but also occurs in parts of Brown, Calumet, Kewaunee, Manitowoc, and Sheboygan counties (Erb and Stieglitz 2007). Enlarged fractures have formed caves at some locations in the Niagara dolomite. Caves open for tours during the summer months are located at the Ledge View Nature Center in Calumet County and at Cherney Maribel Caves County Park in Manitowoc County.

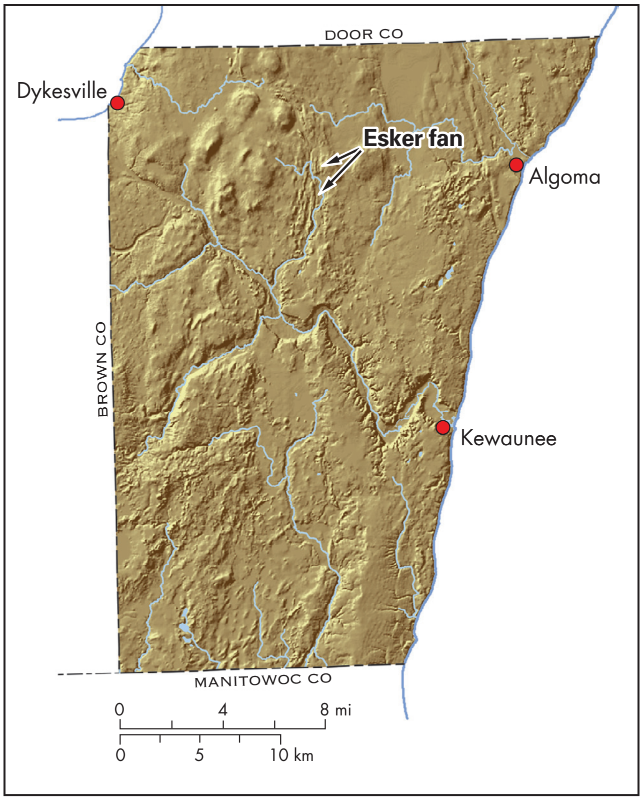


Figure 8.1. *These hills in the Niagara Escarpment in northwest Kewaunee County were likely formed on Silurian coral reefs, as inferred by their shape and arrangement and by the presence of rock outcrops on their crests and sides. The Rosiere esker snakes through the hills from the northwest and breaks into an esker fan as it turns southward. Figure from Clayton (2013), reprinted by permission of the Wisconsin Geological and Natural History Survey.*

Areas underlain by karst bedrock are particularly susceptible to groundwater contamination because surface water readily flows through the fractures (Sherrill 1978, USGS 2007, Bradbury 2009). Also of concern are activities that cut into fractures carrying water, potentially changing the hydrology of the surrounding area. An example of such an occurrence took place around 1999 during a quarry expansion in Brown County (sec. 5, T 24 N R 22 E). The quarry apparently removed a rock barrier and opened an outlet that partially drained a high-quality alvar community to the northeast. The alvar community has supported a large population of the U.S. Threatened dwarf lake iris (*Iris lacustris*) (G. Fewless, UW-Green Bay, personal communication). Portions of this site were designated as Red Banks Alvar State Natural Area in 2001 but concerns remain that the alvar community will decline over time due to quarrying, road construction, residential development, and the increase in weedy plants. These stressors have altered hydrology, fragmented habitat, and led to the loss of community structure and composition. Caution is warranted when quarrying or engaging in earth-moving operations in karst areas because impacts may be far-reaching due to the fractured bedrock.

Devonian bedrock, the youngest in the state, underlies a small area along the Lake Michigan shoreline in Milwaukee and Ozaukee counties. Devonian deposits include the Lake Church, Thiensville, and Milwaukee formations and a very small area of Antrim Shale. The formations are mostly dolomite and argillaceous dolomite (dolomite that contains clay minerals, also called shaly dolomite) and are gray or brownish gray in color. Fossils can be found locally in all these formations except the Antrim Shale (Evans et al. 2004).

Silurian bedrock of the Niagara Escarpment underlies more than half the ecological landscape, including Kewaunee, Manitowoc, Sheboygan, and parts of Ozaukee, Calumet, and Brown counties. Silurian deposits consist of several formations. In Ozaukee County, the uppermost bedrock is the Racine Formation, a light gray, fossiliferous dolomite. Below it lies the Manistique Formation, a medium-gray dolomite, and a sequence of Ordovician bedrock including ironstone of the Neda Formation, shale and dolomite of the Maquoketa Formation, and dolomite of the Sinnipee Group (Evans et al. 2004). In Brown County, the Silurian bedrock includes a small area underlain by the Engadine Formation and additional areas of the Manistique, Burnt Bluff, and Mayville Formations (Luczaj 2010). Silurian bedrock can be more than 600 feet thick in the vicinity of the city of Manitowoc (Trotta 2010).

Older rocks underlie the land toward the west side of the ecological landscape. The bedrock beneath Outagamie County is Ordovician, because Silurian deposits were removed by erosion. The topmost Ordovician layer is the Maquoketa Formation, made up of a bluish shale and shaly dolomite (Brown 2005). It occurs as the uppermost bedrock in only a small portion of the ecological landscape (Mudrey et al. 2005). Most of Outagamie County is underlain by Sinnipee Group dolomites, as is a large portion of Brown County (Brown 2005, Luczaj 2010). Sinnipee Group dolomites contain some limestone and shale and are made up of two formations, the Galena and Platteville. The uppermost Galena Formation is gray- to buff-colored and shaly in the lower beds, while the Platteville Formation is tan to grey and sandy near the bottom. The Sinnipee Group rocks have a maximum thickness of around 200 feet (Brown 2005).

The Ancell Group lies below the Sinnipee Group. It is primarily sandstone of the St. Peter Formation, with thin discontinuous layers of Glenwood Formation shale above it and Readstown Formation shale below. The St. Peter Formation can be a thick layer but has been eroded and exists in this area as channels in the underlying Prairie du Chien Group dolomite (Brown 2005). The Prairie du Chien Group includes the Shakopee and Oneota formations; both are dolomites with some sandstone and shale layers, exhibiting karst features that were formed before deposition of the Ancell Group (Johnson and Simo 2002, Brown 2005).

Cambrian sandstones occur beneath the Prairie du Chien Group. They are the uppermost bedrock layers in the part of the ecological landscape that is within Waupaca County, western Outagamie County, and a portion of southern Shawano

County (Mudrey et al. 1981). They are known only from deep wells in the Fox Cities area, as they are covered by a thick layer of glacial sediment. The topmost Cambrian layers are in the Trempealeau Group, including sandstone of the Jordan Formation, and sandstone and shaly calcareous siltstone of the St. Lawrence Formation. Below the Trempealeau Group is the Tunnel City Group, a shaly, glauconitic sandstone, and finally the Elk Mound Group, primarily made up of sandstone, with pebble layers near the Precambrian basement (Brown 2005).

Precambrian granite bedrock lies around 800 feet deep beneath the land surface near the town of Brillion (Trotta 2010) and at a depth of about 1,875 feet at Sheboygan (Dott and Attig 2004). Because the bedrock surface slopes toward the Lake Michigan basin, the Precambrian rock is deeply buried at the Lake Michigan shoreline, and its elevation rises toward the west. It is the uppermost bedrock in only a very small part of the ecological landscape, in Shawano and Waupaca counties, where all Paleozoic rocks were removed by erosion. The Precambrian rocks are thought to be part of the Montello Batholith, formed by volcanic activity at around 1,760 million years ago, or they may belong to the Wolf River Batholith dating from about 1,480 million years ago (Greenberg et al. 1986, Brown 2005). These rocks are buried beneath thick glacial sediments and have only been identified through well drilling, but they are assumed to be similar to bedrock that underlies extensive areas of the North Central Forest and Northeast Sands ecological landscapes.

The sequence of Ordovician and Cambrian bedrock layers is similar to that described in greater detail in Chapter 22, "Western Coulees and Ridges Ecological Landscape." These deposits underlie much of southern Wisconsin and are a great deal alike throughout the area. A generalized stratigraphic column of bedrock in Door County is given in Stieglitz (1993). Mai and Dott (1985) provided a detailed description of the ***Ordovician sandstone*** of the St. Peter Formation in eastern and southern Wisconsin and also provided cross sectional diagrams of bedrock layers below it.

Landforms and Surficial Geology

The Central Lake Michigan Coastal Ecological Landscape was covered by glacial ice sheets during the last part of the Wisconsin glaciation, which took place from approximately 26,000 until 10,000 years ago. There were undoubtedly a number of ice advances and retreats during the Wisconsin glaciation, but later advances obscured and reworked earlier deposits. Today's landforms are mainly the result of glaciation by the last two readvances of the Green Bay Lobe at about 16,000 and 13,600 years ago (Hooyer 2007) and by the Lake Michigan Lobe at around the same times. The Green Bay Lobe built landforms in the central and western part of the area, and the Lake Michigan Lobe formed the surface of the eastern portion of the ecological landscape. The Green Bay Lobe became separated from the Lake Michigan Lobe as it flowed over bedrock of the Niagara Escarpment. Ice of the Green Bay Lobe was centered over what is now Green Bay and flowed out in a fan-like pattern, moving in a predominantly westerly direction on the northwest side of the Fox River lowland and flowing southeast on the other side (see Figure 3.14 in Chapter 3, "Comparison of Ecological Landscapes"). Glaciers built a land surface composed mostly of till plains and moraines, reworked and overlain in the western part by Glacial Lake Oshkosh (Figure 8.2; Thwaites 1964). The Wisconsin Geological and Natural History Survey has been actively developing information for this part of the state and updated maps and reports will soon be available.

Material deposited by the Green Bay Lobe during its readvances is considered part of the Kewaunee Formation, with source sediments in the Lake Michigan basin. Deposits of the Lake Michigan Lobe during the same time period are also part of the Kewaunee Formation. Much of the boundary of the Central Lake Michigan Coastal Ecological Landscape follows the outer limit of Kewaunee Formation deposits, from the north end of Lake Winnebago to the formation's southern extent in Milwaukee County. Tills of the Kewaunee Formation

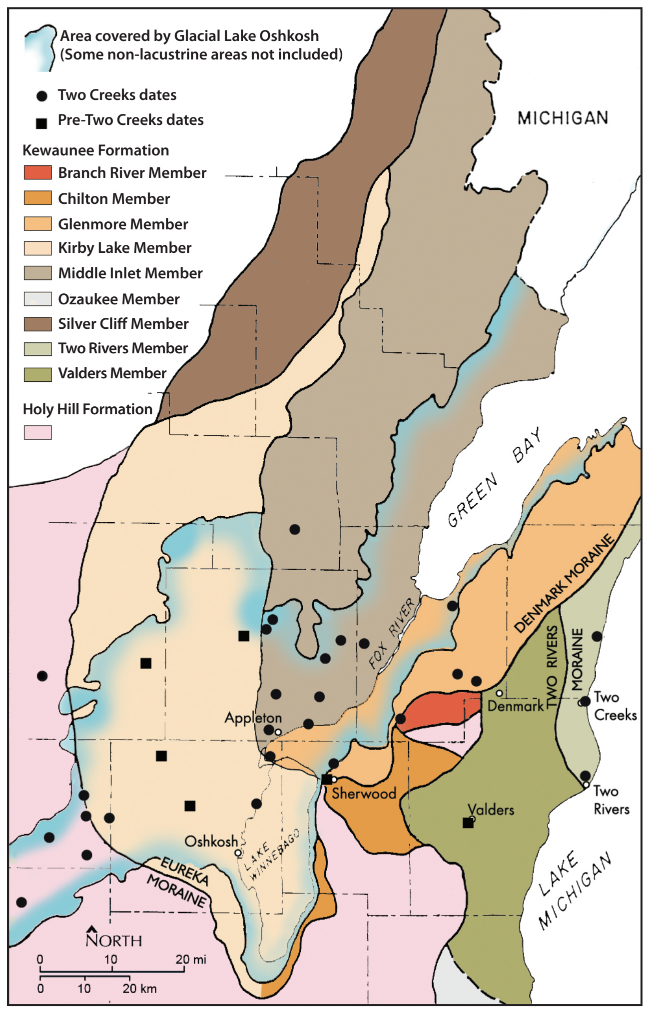


Figure 8.2. *Overview map of stratigraphic units in east-central Wisconsin. Figure from Mickelson et al. (2007), reprinted by permission of the Wisconsin Geological and Natural History Survey.*

are reddish brown and clayey or silty, reworked from fine-grained lake sediments. The Kewaunee Formation has several members, all of which are quite similar in appearance because of their common source material in the Lake Michigan basin. Members are named differently depending on which glacial readvance deposited the materials, whether they originated with the Green Bay Lobe or the Lake Michigan Lobe, and whether the Green Bay deposits lie southeast or northwest of the axis of the Green Bay Lobe (Clayton et al. 2006, Mickelson et al. 2007). Kewaunee Formation Members include the Kirby Lake, Chilton, and Valders deposits originating at around 16,000 years ago and the Middle Inlet, Glenmore and Two Rivers deposits from the last glacial readvance at around 13,600 years ago (Mickelson et al. 2007). The tills have slight differences in clay and silt content, and the older ones have been leached of carbonates to a greater depth. Deposits of the Green Bay Lobe northwest of its main axis are the Kirby Lake and Middle Inlet Members, while those on the southeast of the axis are the Chilton and Glenmore Members. Lake Michigan Lobe deposits are the Valders and Two Rivers Members.

Landforms in the portion of the ecological landscape in Shawano and Waupaca counties and the western part of Outagamie County are made up of Kirby Lake Member deposits (Clayton et al. 2006). They were formed at around 14,200 to 15,600 years ago, during the middle Athelstane phase, in the next-to-last advance of the Green Bay Lobe (Hooyer 2007). The Kirby Lake till is a calcareous clay loam to silty clay loam that in this ecological landscape was mostly submerged and reworked by the fourth and fifth phases of Glacial Lake Oshkosh (Need 1985, Mickelson et al. 2007). McCartney (1980) described it as being generally finer grained and redder than the other Kewaunee Formation tills. Many wetlands occur here due to impeded drainage caused by the fine-textured reworked till, and by the low elevation of the area.

The Chilton Member, also deposited by the middle Athelstane readvance of the Green Bay Lobe, underlies parts of Calumet and Manitowoc counties. This till was deposited southeast of the axis of the Green Bay Lobe at about the same time as the Kirby Lake Member to the northwest. The Chilton is a silty clay loam to clay loam till, leached to depths greater than 28 inches (McCartney 1980, Need 1985). Topography in this area is often rolling (Mickelson and Socha 2004). A lengthy esker north of Brillion was formed by this Green Bay Lobe readvance (McCartney and Mickelson 1982, Mickelson and Socha 2004). During the same general time frame in which the Kirby Lake and Chilton Members were being deposited, the Lake Michigan Lobe deposited the Valders Member, which forms the land surface in most of Manitowoc County, parts of Kewaunee and Sheboygan counties, and a small corner of Brown County (Mickelson et al. 2007). The Valders till has a silt loam to loam texture, and is distinguished from similar till units by its grain size and clay mineralogy (McCartney 1980, Need 1985). Till plains of the Valders Member typically have low relief and include areas with low hummocks (Mickelson and Socha 2004).

The Middle Inlet and Glenmore Members were deposited by the final readvance of the Green Bay Lobe at about 13,600 years ago, during the Late Athelstane phase (Hooyer 2007). Remnant end moraine landforms associated with the Middle Inlet Member run north-south through central Outagamie County. Many areas of these deposits were reworked by the fifth and final stage of Glacial Lake Oshkosh, which flooded much of the recently ***deglaciated*** area as the ice retreated (Hooyer 2007, Mickelson et al. 2007). Middle Inlet till has a calcareous loam or sandy loam texture and differs from other Kewaunee Formation units in having a duller reddish color, sandier texture, and carbonates that have not been leached below 12 inches (McCartney 1980, McCartney and Mickelson 1982). The reworked Middle Inlet sediment forms the surface of most of eastern Outagamie County. A few areas of the till surface were above the water level and existed as islands in Glacial Lake Oshkosh. Part of this area is underlain by Ordovician dolomite and limestone within a depth of 50 feet (Bradbury 2009).

The Glenmore Member is of the same age as the Middle Inlet Member but was deposited to the southeast of the axis of the Green Bay Lobe. Like the Middle Inlet deposits, a portion of the Glenmore till was flooded during the final stage of Glacial Lake Oshkosh (Hooyer 2007, Mickelson et al. 2007). The Glenmore till is a compacted, calcareous, silty clay loam till (Brown et al. 2004, Mickelson and Socha 2004). It has low magnetic susceptibility (a technique that involves exposing sediment samples to a magnetic field, used in differentiating glacial materials based on iron oxide content) (McCartney and Mickelson 1982). Glenmore till covers most of Brown County southeast of the Fox River, about half of Kewaunee County, and southern Door County (Need 1985, Brown et al. 2004, Mickelson et al. 2007). Topography of the till plain is undulating, influenced by the underlying bedrock. The outer extent of the Glenmore deposit is marked by the Denmark Moraine, which runs northeast-southwest through Kewaunee County and parts of southern Door County.

The Two Rivers Member was deposited by the Lake Michigan Lobe at around the same time as the Middle Inlet and Glenmore Members. It is a compacted silty clay loam, distinguished by its grain size distribution and a lack of extensive carbonate leaching (McCartney 1980). It has a low-relief surface and covers the eastern part of Kewaunee County and small areas of Door and Manitowoc counties (Mickelson and Socha 2004). Much of the deposit consists of thin till draped over bedrock or preexisting glacial topography (Clayton 2004). The Two Rivers moraine, possibly built against a bedrock high that stopped this final glacial advance, marks the outer extent of the deposit. The moraine trends north-south through southern Kewaunee and northern Manitowoc counties (Mickelson and Socha 2004).

An older till of the Ozaukee Member of the Kewaunee Formation, deposited prior to development of the Two Creeks Forest, lies at the surface of southeastern Sheboygan, eastern Ozaukee, and northern Milwaukee counties (Mickelson and

Syverson 1997, Clayton et al. 2006). It is this till that is exposed in wave-cut bluffs along Lake Michigan, overlying the older Oak Creek Formation (Schneider 1983). Its till is finer textured and not as consolidated as that of the younger Lake Michigan Lobe deposits, and it has a distinctive clay mineralogy (McCartney 1980, Schneider 1983). The surface generally has gently rolling topography of low relief. An end moraine system associated with this deposit runs mostly north-south through Sheboygan, Ozaukee, and northern Milwaukee counties. The south-flowing portion of the Milwaukee River is an ice-marginal channel that carried meltwater when the Lake Michigan Lobe stood at the end moraine (Mickelson and Syverson 1997, Clayton et al. 2006).

An area where the surface is formed of the considerably older Horicon Member of the Holy Hill Formation, deposited early in the Wisconsin glaciation, occurs in southern Brown and northern Manitowoc counties (Need 1985, Mickelson et al. 2007). The sandier Horicon Member is exposed in this location because later deposits were abraded and removed; generally, the Horicon Member is found lying beneath the more recent Kewaunee Formation deposits (Hooyer 2007). Drumlins are common in parts of the Horicon surface but are not present in most of the rest of the ecological landscape (Need 1985). The Branch River Member of the Kewaunee Formation is also exposed in southern Brown County. It is a deposit of the Green Bay Lobe dating from a readvance at about 16,000 years ago, older than other surface deposits in this ecological landscape with the exception of the Horicon Member (Need 1985, Mickelson et al. 2007).

Deposits of sand and gravel meltwater sediment from previous glaciations occur in some locations where sediments of more recent deposition have been removed by postglacial erosion. One such area lies along Duck Creek west of the city of Green Bay (Need 1985).

Glacial Lake Oshkosh

Glacial Lake Oshkosh existed in a large part of this ecological landscape during times when ice of the Green Bay Lobe stood in the Fox River lowland between present-day Lake Winnebago and the city of Green Bay. Surface water draining northward through the lowland became ponded in front of the ice sheet until finding other outlets, either flowing southwest through the ancestral Wisconsin River valley or east to the Lake Michigan basin. Five stages of Glacial Lake Oshkosh have been described (Hooyer 2007). The lake was at its highest level of elevation during the first stage at about 19,500 years ago, and additional significant stages occurred at around 15,000 and 13,400 years ago (Figure 8.3; Hooyer 2007). Glacial Lake Oshkosh varied in size depending on the location of the ice sheet; at its maximum it covered around 1.4 million acres, primarily within the Central Lake Michigan Coastal, Northeast Sands, and Southeast Glacial Plains ecological landscapes. Protruding morainal hills and bedrock-cored landforms were islands in the glacial lake. Lacustrine silts and clays, formed of reworked till as well as materials carried by meltwater, were deposited from deep waters, while beach ridges, terraces, and dunes formed near shorelines when sandy sediments were present. In other locations, shorelines are evidenced by boulder fields where silts and clays were removed by wave action (Hooyer 2007, Hooyer and Mode 2007).

The final stage of Glacial Lake Oshkosh ended when the Green Bay Lobe receded sufficiently to reopen outlets to the Lake Michigan basin at about 13,000 years ago. There were four outlets that successively drained the glacial lake, the highest of which was through the Manitowoc River valley. The Neshota/West Twin river valleys, slightly to the north, were the next channels to be utilized as the Green Bay Lobe continued to recede. Later outlets were through the Kewaunee River valley and finally the Ahnapee River valley (Hooyer 2007). The former drainage channels are in bedrock valleys that cut across Door, Kewaunee, Brown, Calumet, and Manitowoc counties in a northwest-to-southeast direction. These valleys may have been preglacial features that were originally cut by streams running into an

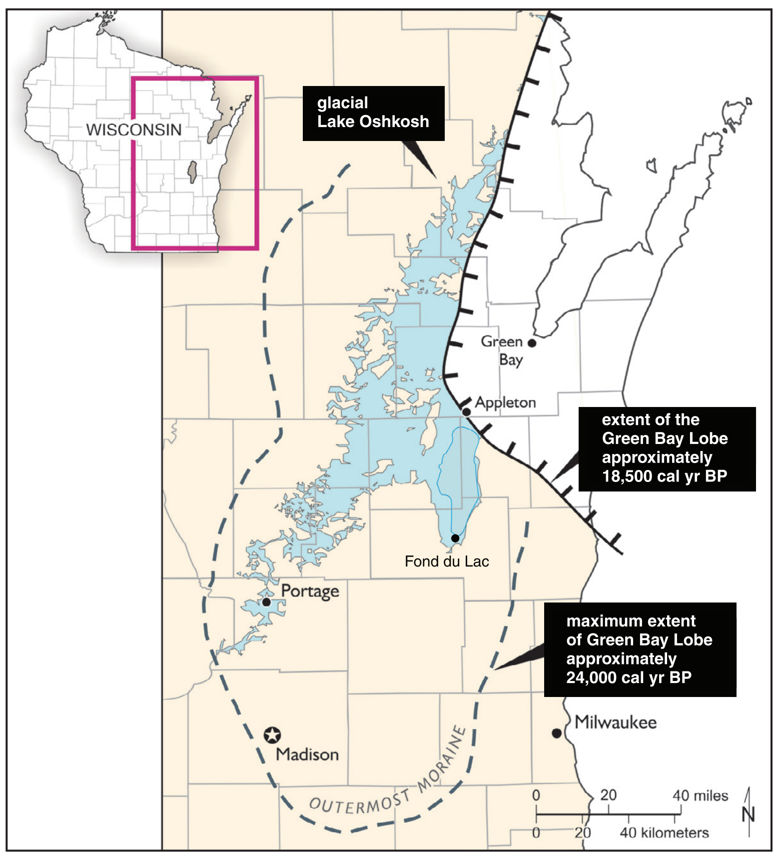


Figure 8.3. *Extent of Glacial Lake Oshkosh during the Pleistocene. Figure from Hooyer (2007), reprinted by permission of the Wisconsin Geological and Natural History Survey.*

ancient river in the Lake Michigan basin and then deepened by glacial activity when tongues of ice that preceded the main glacier filled and scoured the valleys in a process similar to the creation of fjords and fjards (drowned glacial valleys) (Dutch 1980, Schneider 1993b). The valleys were likely deepened further by drainage from Glacial Lake Oshkosh. The lake's final drainage may have taken place rapidly, as evidenced by the width of its spillway channels and the steep slopes of their valley sides in many places (Hooyer 2007).

Two Creeks Forest Bed

Vegetation known as the Two Creeks Forest developed during a relatively warm climatic period between about 14,400 and 13,100 years ago, when the Green Bay Lobe melted back from the Lake Michigan basin between the Middle and Late Athelstane glacial phases. Wood and other forest litter was found buried under sediment south of the village of Two Creeks along the Lake Michigan shoreline. This location was first described by Goldthwait in 1907 and has become well known to geologists, although now the stratigraphic sequence at the original site is poorly exposed due to lakeshore erosion. The type location for the Two Creeks forest bed is located in sec. 2, T 21 N, R 24 E, just south of the Manitowoc-Kewaunee county line (Mickelson et al. 2007). Many more Two Creeks forest sites have subsequently been discovered in east-central Wisconsin, and the forest is now known to have covered approximately 600,000 acres at its largest extent, mostly within the Central Lake Michigan Coastal Ecological Landscape (McCartney and Mickelson 1982, Hooyer 2007, Panyushkina and Leavitt 2007). The forest was dominated by black spruce (*Picea mariana)* and tamarack and included a component of white spruce (*Picea glauca)* and balsam fir (*Abies balsamea)* (Schweger 1969, Maher 1970). Sedges and mosses were common on the forest floor (Schweger 1969). The shrub buffaloberry (*Shepherdia canadensis*), a species associated with boreal spruce forests and mountainous areas, was abundant during the first part of the interglacial phase, likely as a colonizer during early succession (Black 1970). Mollusks, insects, and fungi have also been studied. Several Two Creeks forest sites are described in the guidebook for the 2007 Midwest Friends of the Pleistocene Field Conference, including an unusual one in Calumet County that appears to have been an American beaver (*Castor canandensis)* dam (Mode et al. 2007). The last major readvance of the Green Bay Lobe, during the Late Athelstane phase at about 13,500 years ago, again blocked drainage outlets from the Fox River lowlands. Glacial Lake Oshkosh formed for the last time, west and south of the ice sheet. Much of the Two Creeks Forest was drowned by the glacial lake and buried in lacustrine sediments and in other areas was directly crushed by advancing glacial ice (Mickelson et al. 2007). The Green Bay Lobe's final readvance extended as far west as the current city of Appleton, burying the forest beneath tills of the Middle Inlet and Glenmore Members at about the same time that the Lake Michigan Lobe deposited the Two Rivers till over the forest in the eastern part of the ecological landscape (Hooyer 2007).

A large dune field approximately 10 miles long lies along the Wolf River at the Shawano-Outagamie county line. The dunes likely formed atop a sandy delta where the ancestral Wolf and Embarrass rivers flowed into Glacial Lake Oshkosh after the lake drained. The dune field is described as Stop 3 in the guidebook for the 2007 Midwest Friends of the Pleistocene Field Conference (Forman and Hooyer 2007).

Inter- and Postglacial Lakes in the Lake Michigan Basin

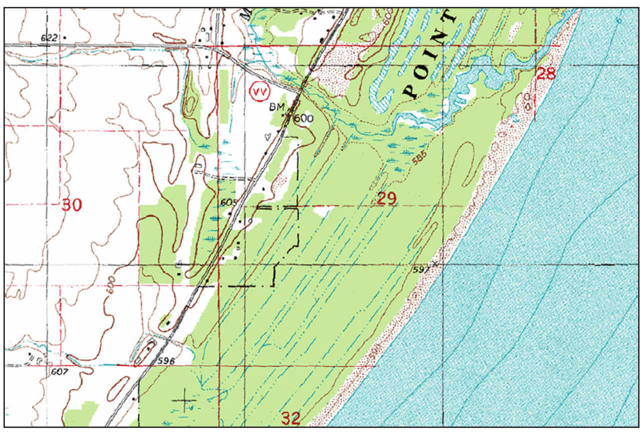
Lakeshore features originating from late-glacial and postglacial lakes in the Lake Michigan basin occur here as well as in the other ecological landscapes along the lake. These lakes formed ahead of the glacier when the outlet from the Lake Michigan basin at the Straits of Mackinac was blocked by ice. Former shorelines of the lakes are present at many locations at elevations higher than the current Lake Michigan. The oldest and highest shorelines date from about 10,000 to 11,000 years ago, when Glacial Lake Algonquin occupied the basins of Lakes Michigan and Huron at water levels about 20 feet higher than the average current lake levels of 580 feet (Schneider 1993b, Dott and Attig 2004).

The ***Nipissing Great Lakes*** formed at about 4,000 to 5,000 years ago, when isostatic uplift closed outlets from the Lake Michigan basin and water levels again rose to about 20 feet higher than present. Several stages of decreasing lake levels occurred as new outlets opened, until Lake Michigan reached its modern levels at about 3,000 years ago (Dott 1993). Nipissing shorelines are common in this ecological landscape, evidenced by beach ridges, dunes, and wave-cut terraces (Schneider 1993b, Dott and Attig 2004).

Isostatic adjustment following glaciation has raised the northern part of the Great Lakes region in relation to southern Lake Michigan. Algonquin shorelines along the Door Peninsula are preserved because they were raised before the Nipissing Great Lakes existed, but Algonquin shorelines along southern Lake Michigan were not raised and were obscured when water levels rose again during the Nipissing Great Lakes period (Dott and Attig 2004). The current rate of change in elevation contributes about 3.5 inches of elevation per century at Sturgeon Bay as compared with the southern shore of Lake Michigan. The rate of relative uplift diminishes to the south. It is around 1.2 inches per century in Manitowoc County but scarcely noticeable at Milwaukee (Larsen 1994). Clark and Ehlers (1993) described an Algonquin shoreline in Howard, near Green Bay, but Algonquin shorelines are generally inconspicuous and difficult to distinguish from Nipissing shorelines in most of this ecological landscape (Need 1985, Schneider 1993b).

A lake plain of Glacial Lake Nipissing, formed of silty lacustrine material, is mapped along the west shore of Green Bay in Brown County and clayey Lake Nipissing sediment occurs around the mouth of the Fox River (Need 1985). Nipissing deposits occur along the Lake Michigan shoreline

Great Lakes ridge-and-swale complex along Lake Michigan. Most of this landscape was historically forested but has been cleared and heavily developed. Manitowoc County. Photo by National Agricultural Imagery Program.



U.S. Geological Survey 7.5′ topographic map showing ridge-and-swale complex parallel to the Lake Michigan shore. Few large patches of forest remain in this landscape. Manitowoc County. Map courtesy of U.S. Geological Survey.

in Manitowoc County, where they form a series of abandoned beach terraces, beach ridges, and dunes with wetland swales (Hooyer and Mode 2007). A shoreline at the west edge of Point Beach State Forest was formed by the highest level of Lake Nipissing (Dott and Attig 2004). In Ozaukee County, Nipissing and Algonquin terraces occur along the shoreline north of Port Washington (Mickelson and Syverson 1997). Glacial Lake Nipissing deposits are generally found at elevations below 610 feet (Hooyer and Mode 2007).

Lake bluffs formed of glacial till are common along the Lake Michigan shoreline, particularly where end moraines are adjacent to the shore. Peters (1983) described locations of the lake bluffs and classified them according to height and angle. In general, the highest and steepest bluffs are near Milwaukee, in the Southern Lake Michigan Coastal Ecological Landscape, but bluffs also occur intermittently along the lakeshore in this ecological landscape. Some bluffs in Ozaukee County are up to 120 feet high, but many of the bluffs farther north are lower, typically ranging from 20 to 65 feet high. Bluff faces exposed by lake erosion are ideal for studying glacial sediments, and it was in one of these areas that the Two Creeks Forest Bed was first discovered.

At localized areas, ***proglacial*** streams formed outwash deposits, including outwash plains, terraces, and fans, but the extent of outwash deposits is small in this ecological landscape. Postglacial erosion by streams, followed by redeposition of the sediment, led to the development of floodplains and terraces along rivers. The silty aeolian loess that was deposited over most of the state following glaciation is lacking here, and is less than 6 inches thick in most of the ecological landscape (Hole 1976).

The Central Lake Michigan Coastal Ecological Landscape includes three ecological units at the Subsection level, including the Outagamie Loamy Till and Silty Lake Plain Subsection (212 Za), the Green Bay Clayey and Silty Lake Plain Subsection (212Zb), and the Manitowoc Till Plain Subsection (212Zc) (Cleland et al. 1997). (For details on Subsections, see the "Introduction" in Part 1 of this publication and the "Ecological Landscapes, NHFEU Provinces, Sections, and Subsections" map in Appendix G, "Statewide Maps," in Part 3.) A map showing ecological units at the finer-scaled Landtype Association (LTA) level (WLTA Project Team 2002) within the Subsections, along with the descriptions of the LTAs, can be found in Appendix 8.K.

Topography and Elevation

Elevation ranges from about 580 to 1,020 feet (177 to 311 meters) in the Central Lake Michigan Coastal Ecological Landscape. The lowest elevations are at the shores of Lake Michigan, but lake levels fluctuate by around 7.5 feet depending on climate (Thompson and Baedke 2000). The highest point is located at Cherneyville Hill, in a rolling, collapsed end moraine in Kewaunee County (northeast of sec. 32, T 23 N, R 23 E). Topography is nearly level to undulating on lake plains, predominantly undulating on till plains, and undulating to rolling on end moraines. There are a few areas of hilly and steep topography in river valleys (e.g., along much of the Kewaunee River, particularly in its lower ***reaches***).

Soils

Most upland soils in the Central Lake Michigan Coastal Ecological Landscape were formed in reddish-brown calcareous loamy till or lacustrine deposits on moraines, till plains, and lake plains. The dominant soil is moderately well drained and loamy or clayey with a silt loam surface. Drainage classes range from well drained to somewhat poorly drained. Soils generally have moderate to very slow permeability and moderate to very high available water capacity. Soils that are shallow to limestone or dolomite bedrock occur here. A few areas have soils formed in acid wind-blown sand or outwash sand. Soils along the Lake Michigan shoreline are formed in calcareous clayey, silty, and sandy lacustrine deposits, acid to calcareous wave-deposited beach sand, and wind-blown sediments. Most lowland soils are very poorly drained non-acid muck, while some are in poorly drained outwash, till, and lacustrine materials. The major river valleys have soils formed in sandy, loamy, or silty alluvium; some areas are subject to periodic flooding.

Hydrology

Hydrology of the Central Lake Michigan Coastal Ecological Landscape is dominated by its proximity to Lake Michigan, which has influenced the climate, created unique landforms, and is responsible in part for the presence and distribution of rare species. The shoreline constitutes a major flyway for migratory birds. Most of the major cities in this ecological landscape are located at the estuarine mouths of rivers entering Lake Michigan.

This ecological landscape was entirely glaciated. Extensive areas of nearly level lake plain occur close to Lake Michigan and south and west of Green Bay in the bed of Glacial Lake Oshkosh (UWSP 2009). Rolling terrain characteristic of areas on landforms such as ground moraine, end moraine, or collapsed outwash is common. It exhibits drainage patterns characteristic of extensive ground moraine, with poorly drained areas containing wetlands. Relatively few lakes occur here, and almost all of them are under 50 acres in size. These include riverine oxbow lakes, which are confined to the old channels of the larger rivers, especially the Wolf.

The western and central portions of this ecological landscape contain many of the small lakes, and the streams here are characterized by extensive meandered sections. Rivers include the Wolf, Embarrass, Pigeon, and Shioc. The Wolf and Embarrass rivers flow through extensive floodplain forests of silver maple, green ash, and swamp white oak. Areas of poorly drained glacial lake plain or ground moraine support wet forests, some of them extensive, of black and green ashes, red maple, elms, tamarack, and northern white-cedar.

Basins

This agriculture-dominated ecological landscape is drained by seven major basins: Wolf River (from south of Shawano to the Embarrass River); lower Fox (northerly 80% of this basin is in the Central Lake Michigan Coastal Ecological Landscape); Green Bay (a small sliver along the west shore of Green Bay); Twin-Door-Kewaunee (southern 65% of the ecological landscape); Manitowoc (about 75%); Sheboygan (east half); and the Milwaukee River basin (a small southern sliver along Lake Michigan). Within these basins there are 26 watersheds (see Appendix 8.A at the end of this chapter) that lie entirely or partially within this ecological landscape. About 40% of these watersheds drain into the Green Bay portion of Lake Michigan, directly or via the Wolf and Fox rivers. The rest of the streams, from south of Sturgeon Bay to Milwaukee, flow into the open waters of Lake Michigan.

Wisconsin DNR basin plans list a number of high priority concerns in this ecological landscape, namely development of rural areas, including agricultural land; the need to protect natural areas, including wetlands; degradation of water quality; management and disposal of farm animal waste; public education about natural resource values; and soil erosion, including erosion on the Lake Michigan bluffs. Lesser priority concerns include groundwater contamination, sustainable and healthy fisheries, adequate public access to natural resources, stormwater runoff, and managing natural resources in a public-private partnership.

Lake Michigan

There are 17,017 miles of Great Lakes shoreline, including 5,521 shoreline miles in the United States. Lake Michigan, including Green Bay and all islands, has a shoreline of 1,638 miles. The Central Lake Michigan Coastal contains about 115 miles of coastline along Lake Michigan's west shore, plus another 60 miles of the Green Bay shore, totaling roughly 175 miles of Lake Michigan shoreline. This ecological landscape contains about 3% of Lake Michigan's coastline, or 1% of all the Great Lakes coastline of North America.

The eastern edge of the ecological landscape is heavily influenced by the cool waters of Lake Michigan (925 feet maximum depth), which has created a cool, moist climate and distinct landforms, affected by phenomena such as water level fluctuations, fogs, wave spray, storm wave impacts, ice push, and deposition and erosion of sediments. This physical setting has promoted a unique set of biotic communities, species assemblages, and natural community ***mosaics*** of unusual composition, limited geographic distribution, and high ecological value. Species endemic to Great Lakes shoreline habitats occur here. Undeveloped shoreline habitats and the relatively clean, open waters of Lake Michigan in this ecological landscape are highly significant to migratory birds (Steele 2007). Lake Michigan is a Conservation Opportunity Area of global significance (WDNR 2008d). The Wisconsin shore of Lake Michigan within this ecological landscape has shoreline features shaped by wave and river dynamics that made the mouths of rivers along the lake suitable sites for small harbors. These are the present-day locations of the cities of Algoma, Kewaunee, Manitowoc, Two Rivers, Sheboygan, and Port Washington.

The lake's fishery, including lake whitefish (*Coregonus clupeaformis*), lake trout (*Salvelinus namaycush*), ciscoes (*Coregonus* spp.), and yellow perch (*Perca flavescen*), was formerly of great commercial significance, but overexploitation of the resource, habitat degradation, and the losses from depredations by exotic species such as the sea lamprey (*Petromyzon marinus*) and others led to the disappearance or drastic reduction of some species by 1950, greatly diminishing the commercial fishery's economic importance. The commercial lake trout fishery has been replaced, to a degree, by a sport fishery that is based on the introduced nonnative salmonids that now occupy the top predator positions in Lake Michigan. One native commercially important species, the lake whitefish, remains locally abundant.

The recent invasion of Lake Michigan (and lakes Huron and Ontario) by the quagga mussel (*Dreissena bugensis*) is of concern. Quagga mussels may reduce the prey base for populations of introduced, nonnative salmonids and be a factor in their decline. Researchers are trying to conclusively determine the cause of these ecosystem changes and what it might mean for a return of the formerly abundant native sport fish species (Erikson 2009).

Topographic and meteorological factors make Lake Michigan a potential site for wind power development. The offshore stretch from Manitowoc to Sheboygan is rated as one of the areas of highest mean annual wind power densities in the state (see "Renewable Energy" in the "Socioeconomic Characteristics" section of this chapter) and has attracted interest from wind energy developers, but no specific proposals have been introduced to state or federal regulatory agencies (Content 2008). A number of public agencies would likely be involved in reviewing any formal proposal to construct wind towers in Lake Michigan to evaluate potential impacts to lake bed habitat, aquatic life, migratory birds, especially waterbirds, and other wildlife. Concurrent state and federal jurisdiction over the lake bed as a matter of public trust would be a primary issue that would need to be resolved.

Fertile and biologically very productive, Green Bay remains an ecologically important part of Lake Michigan. It covers about 1,396 square miles (6.25% of the total area of the lake) and has a mean depth of 60 feet (the extreme southern end of the bay has an average depth of only 9.8 feet). This large, shallow bay cools faster than Lake Michigan in the fall and becomes thermally stratified earlier in the summer. The southern bay averages more than 7°C warmer than the northern bay (in the adjacent Northern Lake Michigan Coastal Ecological Landscape) and 12°C warmer than deep lake water.

Currents in lower Green Bay tend to be counter-clockwise, moving northerly on the eastern side of the bay, then swinging west and south. In addition, when the Fox River currents enter the bay, currents flow eastward, due to the Coriolis effect of the earth's rotation. Historically, the river currents kept the east shore of lower Green Bay flushed clean, maintaining cobble, boulders, and sandy beaches, while the west shore, with a slower current, accumulated more soft sediments and supported extensive cat-tail marshes and wild rice (*Zizania* spp.) beds (Bertrand et al. 1976).

Because it is long and narrow, Green Bay is subject to short-term, irregular water level oscillations. These oscillations, or ***seiches***, are caused by strong wind, sudden changes in barometric pressure, currents, and other physical factors. A normal seiche may change water levels by a foot or more in a few hours, up to three or four times a day. Some seiche events are powerful enough to reverse the flow of the Fox River as far as 7 miles upstream from the river's mouth at Green Bay. In 1966 one seiche created upstream flows from the river mouth of more than 280 cubic meters per second (10,000 cfs). In 1957 a seiche created an increase in river level of 4.7 feet (1.43 meters) in 17 hours on the East River, a tributary of the Fox. Green Bay is also slightly affected by a semi-diurnal lunar tide (Bertrand et al. 1976). These periodic water level fluctuations present an adaptation challenge for aquatic plants and animals beyond the normal seasonal variations in hydrological conditions.

Green Bay has been heavily used since Euro-American settlement for industry, commercial fishing, shipping, recreation, and tourism. Despite a past history of significant industrial pollution (see the "Water Quality" section), Green Bay supports populations of smallmouth bass (*Micropteris dolomieu)*, walleye (*Sander vitreus*), northern pike (*Esox lucius*), and yellow perch that are much sought after by recreational anglers. Shallow bays containing wetlands of emergent marsh and beds of submergent vegetation are critical spawning and fry-rearing habitat for these and other species. The cobble and boulder bottom along much of the east shore of Green Bay is ideal habitat for smallmouth bass, which feed heavily on crayfish, mayflies, dragonfly larvae, and other organisms inhabiting rocky bays and offshore shoals (WDNR 2001d).

Green Bay has undergone extensive changes due to a variety of factors. Two of the most significant have been industrial contamination (see "Water Quality") and invasion by a host of nonnative aquatic species. Other important factors include residential and recreational developments (which often have associated hydrological modifications such as ditching, diking, channelization, pond construction, and groundwater withdrawals), agricultural runoff (which is common from lands south and west of Green Bay), and infrastructure such as roads, power lines, and ditches (which can disrupt hydrology, serve as a source of pollutants, facilitate the spread of invasive species, and act as a physical barrier to some species). Poorly designed culverts and bridge crossings have been a significant problem at some locations because they may alter water levels and vegetation and act as barriers to the movement of aquatic organisms (including fish). A shipping canal has been dredged through lower Green Bay, affecting not only the channel itself but also areas where the spoils from ongoing dredging have been deposited (e.g., Renard Island).

While development pressures in Green Bay have created concerns over the viability of remaining wetlands and marshes, a large portion of the wetlands along the west shore of Green Bay is in public ownership as the Green Bay West Shores Wildlife Area (Little Tail, Sensiba, Long Tail, and Peats Lake units). Various government and private conservation programs are taking steps, including chemical treatment and follow-up prescribed burning, to restore as much marsh habitat as possible, since it became infested with invasive plants such as common reed and purple loosestrife. Progress has been slow due to the resilient nature of these invasives, particularly common reed.

Inland Lakes

According to the Wisconsin DNR's 24K Hydrography Geodatabase (WDNR 2014b), the Central Lake Michigan Coastal Ecological Landscape holds only 74 named inland lakes, the seventh fewest among all ecological landscapes. Of these, few are of a size or structure that can accommodate motorized boating and other recreational pursuits. About half are seepage lakes and total only 1,925 acres, the third smallest

Wolf River and complex floodplain, Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

water area of named lakes among all ecological landscapes. However, there are also 3,830 acres of very small unnamed lakes and ponds (3,611 of them in total), the 10th highest area of unnamed lakes among all ecological landscapes. Most unnamed lakes are small bog, kettle, or pothole lakes, with many less than 1 acre in size. Others may be shallow lakes of 20 to 40 acres or more, associated with wetlands.

Most of the lakes here are relatively small, with the majority covering less than 50 acres. Most have limited fish populations, but some have public access and are locally popular with anglers. Many have shifted from being slightly eutrophic (***trophic state*** index [TSI] around 50) to more heavily eutrophic (TSI around 60 to 65) due to agricultural and other runoff, and most are infested with nonnative invasive species, such as zebra mussels (*Dreissena polymorpha*) and Eurasian water-milfoil (*Myriophyllum spicatum*). Examples of some of the more well-documented and sometimes heavily visited inland lakes in this ecological landscape are Carstens, Jetzers, Big and Little Gerber, Lily, Heidmann, Glomski, and Round lakes.

Exemplifying ecological problems encountered in many inland lakes in this ecological landscape, Carstens Lake in Manitowoc County is 21 acres with a 28-foot maximum depth that supports largemouth bass (*Micropterus salmoides*), along with panfish. In the 1950s, Carstens Lake had no residences along its shore. The lakeshore is now moderately developed with seasonal and year-round homes. Agricultural runoff of sediments and nutrients caused the water quality of the lake to decline. Black bullhead (*Ameiurus melas*) and common carp exacerbated the existing high water turbidity. Low dissolved oxygen caused by runoff ultimately resulted in a fish kill in 1977. An effort was made to control black bullhead and carp by seine netting and removing those species from the lake. Seine netting over three summers failed to control carp and bullheads enough to allow the expansion of native fish populations. In 1982 the lake was treated with rotenone to eliminate all fish. The lake was subsequently restocked with largemouth bass, yellow perch, and northern pike (Surendonk 1999). Illegal stocking added bluegill (*Lepomis macrochirus*) and black crappie (*Pomoxis nigromaculatus*). Although the game fish community was restored following the rotenone treatment, the source of poor water quality (agricultural runoff) was not addressed. A weir was constructed to stop carp from entering the lake, but worsening water quality and illegal stocking of planktivores (bluegills and crappies) caused Carstens Lake to revert to its pretreatment condition.

Impoundments

Several of the major rivers and many small streams have been dammed since Euro-American settlement, causing a loss of habitat and habitat connectivity, creating barriers to aquatic organisms, increasing water temperatures, and impairing local water quality. A large number of streams remain impounded by 161 dams in this ecological landscape. These impoundments cover 6,891 acres but hold less than 14,000 acre-feet of water (WDNR 2014b). Twenty-one dams have been removed from streams here to help improve water quality, allow fish passage, resolve issues with lack of dam maintenance, or for other reasons. Impoundments and their dams range from very large to very small and exhibit a wide range of water quality and habitat conditions.

The upper Kaukauna Dam impounds 120 acres on the lower Fox River, and Rapide Croche Dam has created a 530-acre reservoir (WDNR 2014b). These and other locks and dams on the Fox River are maintained for recreational purposes, and several are licensed for hydroelectric power production for the paper industry. Manawa Dam impounds 192 acres on the North Branch of the Little Wolf River. Its outlet is the start of a 15-mile free-flowing stretch of river that joins another 25 free-flowing miles of the main stem of the Wolf River, which is a Priority ***Stream Segment*** (see "Rivers and Streams," below). The impoundment has received a lake planning grant to help address water quality concerns caused by poor agricultural animal waste management. The Clintonville Dam impoundment on the Pigeon River is 163 acres and contains both largemouth bass and panfish.

Hingham Mill Pond (36 acres) and Waldo Mill Pond (40 acres) are small impoundments whose dams present barriers to fish migration on the Onion River (WDNR 2014b). Their fish communities are very limited due to shallow water and eutrophic conditions. A number of dams on state wildlife areas create small impoundments for waterfowl and other birds, although the Mud Creek Dam at Collins Marsh Wildlife Area impounds 2,000 acres.

Rivers and Streams

There are 1,485 miles of perennial streams flowing through this ecological landscape, according to the Wisconsin DNR's Hydrography Geodatabase (WDNR 2014b). The western portion of this ecological landscape is drained by a number of streams that are significant for their ecological as well as recreational values. These include about 32 miles of the Wolf River in Shawano, Waupaca, and Outagamie counties, about 16 miles of the middle Embarrass River, 14 miles of the Little Wolf River, and 12 miles of the Shioc River.

Many headwaters creeks and other smaller streams depend on stored groundwater for base flow. However, much of this ecological landscape was cleared of forest that served to limit stormwater sheet flow and promoted groundwater recharge. Consequently, most of these streams now exhibit ***flashy flow***s due to higher rates of runoff and abnormally low flows during dry periods. Some streams become intermittent, drying up completely when the shallow groundwater table is depleted.

The ecological significance of a few of the streams and rivers here (Wolf, Embarrass, and Shioc) is high because they provide a range of habitat conditions that support a large number of species, support high numbers of some species, or provide habitat for rare species. This high quality aquatic habitat is a function of areas of low development and the presence of functional wetlands of good quality and large size in river floodplains. However, the conservation status of many of the smaller streams here has not been determined, due to a lack of data for stream invertebrates and other factors (W.A. Smith, Wisconsin DNR, personal communication).

The lower section of the Wolf River is renowned for its extensive spawning habitat, which is vital to what is believed to be the world's largest and most secure population of lake sturgeon (*Acipenser fulvescens*) (Bruch and Binkowski 2002, Smith 2011). Sturgeon migrate upstream from Lake Winnebago and other connected lakes (such as the upper Winnebago Pool lakes) in the spring to lay eggs, often in rock-bottomed stretches of the lower Wolf River. The Wolf is also renowned for its spring migration of walleye from Lake Winnebago. The shoal (or speckled) chub (*Macrhybopsis hyostoma*, formerly known as *M. aestivalis*) population of the Wolf River is the only known occurrence of this species in the entire Great Lakes basin. All other known occurrences are in the Mississippi River major basin. Two of the only four Great Lakes basin populations of the western sand darter (*Ammocrypta clara*) occur in the Wolf and Embarrass rivers (Lyons et al. 2000, Epstein et al. 2002a) (the other two being in the Waupaca and Menominee rivers). Of the four populations, the lower Wolf River appears to support the largest number of individuals (J. Lyons, Wisconsin DNR unpublished data). The lower Wolf, Little Wolf, and lower Embarrass rivers are all designated by the Wisconsin DNR and The Nature Conservancy as Priority Stream Segments for conservation management, due to the ecological significance of these streams (Epstein et al. 2002a).

Conservation status of many of the smaller streams here as stand-alone entities has not been determined. However, these smaller streams are integral parts of highly significant riverine ecosystems, a key consideration is how they are managed and affected by local land uses.

Springs that supply clear, clean, cold water for coldwater streams are rare in this ecological landscape. Consequently, there are very few coldwater streams and few stream segments offering coldwater habitat. A few streams with suitable coldwater habitat conditions have been designated as trout streams and are distributed throughout the ecological landscape. Beaver, Little Scarboro, and Whitcomb creeks are examples of coldwater streams that are Class I trout streams with self-sustaining trout populations. Little Scarboro Creek has a native brook trout (*Salvelinus fontinalis*) population.

Coolwater streams in this ecological landscape are also generally associated with spring flows. A few coolwater streams within this ecological landscape in Kewaunee and Manitowoc counties support limited populations of trout. These include Casco, Scarboro, Tisch Mills, Kriwanek, and Jambo creeks, and the upper East Twin River. The lower North Branch of the Embarrass River is a coolwater stream formed by coldwater tributaries. Below the Pella Dam, this stream is rich in aquatic invertebrate species and other fauna, and features a floodplain similar to the lower reaches of the Wolf River, although it is much less extensive.

To the south and closer to Green Bay, land use becomes more agricultural, and warmwater rivers are influenced, sometimes heavily, by agricultural, industrial, and residential development. Siltation, loss of floodplain wetlands and upland forest, erosion of soils from row crops, industrial pollutants, urban stormwater runoff, and hydrological alterations all serve to degrade water quality and habitat values of the rivers in this area.

Embarrass River bottoms, Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

Kewaunee wetlands. Photo by Emmet Judziewicz.

The Fox River is the most industrialized and altered river in this ecological landscape. It flows through the western part of the ecological landscape and through many cities before it enters the city of Green Bay. It is constrained by the Fox River Locks System that includes 17 locks and 12 dams between Lake Winnebago and the De Pere Dam. All locks and 10 of the dams had been operated by the U.S. Army Corps of Engineers since 1872. (The remaining two dams—Combined Locks and Kaukauna City Plant dams—are owned and operated by Kaukauna Utilities to produce electricity). Over time, lock traffic changed from primarily commercial vessels to primarily recreational vessels. A sea lamprey barrier was established at the Rapide Croche lock and dam in 1987 to stop the upstream movement of the lamprey and other aquatic invasive species into the Lake Winnebago, Fox, and Wolf River basins. The 17 locks were closed by the federal government in 1988, and the State of Wisconsin took over the system in 2000. The state began a rehabilitation project in 2006, with a completion target of 2015. Plans are to reopen 16 of the 17 locks. The lock at Rapide Croche will remain closed to prevent the upstream movement of sea lamprey and other aquatic invasive species.

The Wolf River runs south and west through the western edge of this ecological landscape, eventually turning south and entering the Winnebago Pool lakes in the Southeast Glacial Plains Ecological Landscape. From there the Wolf becomes part of the Fox River system. Portions of the middle and lower Wolf River flow for about 60 miles through this ecological landscape. The Wolf River here is very different from the upper reaches, which are rocky, swift, and shallow in some stretches and flow through an almost entirely forested area. In the Central Lake Michigan Coastal Ecological Landscape, the Wolf River is a low-gradient, deeper stream, with a broad floodplain that supports extensive bottomland hardwood forests and other wetland types. Land cover outside of the river's floodplain is dominated by agriculture (row crops, hay, and pasture). This portion of the Wolf River and its floodplain support important populations of many aquatic "Species of Greatest Conservation Need," especially mussels and dragonflies, as well as rare fish, birds, and mammals. The mussel species diversity in this reach remains very high. The dikes associated with ditches in a wetland area known as Hortonville Flats within the Wolf River floodplain restrict water flow across the floodplain and diminish the success of walleye spawning, but it is not known whether these barriers have any notable effect on any other species.

The Embarrass River is an ***Exceptional Resource Water***, with a diverse warmwater sport fish community in most of this ecological landscape, especially for smallmouth bass. The river is also popular for canoeing. The main stem of the Embarrass River is an important sturgeon spawning stream up to the Pella Dam. However, severely polluted runoff has been noted at its confluence with the Wolf River (in the vicinity of New London) due to animal waste runoff from barnyards and feedlots, along with soil erosion and high turbidity, following high precipitation events such as summer storms (WDNR 2001c). The current county land and water conservation plan proposes financial incentives and standards to address these problems, with goals to reduce nitrogen, phosphorus, and other pollutants by at least 25% (Shawano County 2009).

The Little Wolf River is a tributary to the Wolf River and has a clean gravel substrate and good invertebrate diversity, including populations of the pygmy snaketail dragonfly (*Ophiogomphus howei*), a Wisconsin Threatened species in 2009 (WDNR 2009). Flowing through the far western lobe of this ecological landscape, the Little Wolf joins the Wolf River in southeastern Waupaca County.

The Shioc River fishery is derived from the Wolf River, and the Shioc is important during spring when walleye and bass use the river for spawning. This river experiences extreme water level fluctuations, with low water and isolated pools during the summer months. The Shioc River and its tributaries flow through agricultural land with little or no buffering vegetation.

Springs

There are only 57 mapped springs in the Central Lake Michigan Coastal Ecological Landscape (Macholl 2007). The only concentration of mapped springs here is along the Niagara Escarpment, with other springs widely scattered. A part of the Central Lake Michigan Coastal notably lacking in springs is the area formerly covered by Glacial Lake Oshkosh (see Figure 8.3), consisting of most of Outagamie County and the eastern half of Waupaca County. This is reflected in the fact that there are no high quality coldwater streams here. The coldwater flow from springs is critical to maintaining the low temperature and high dissolved oxygen content vital to the health of the coldwater stream community, including trout. The spring flow helps to support native stream invertebrates by helping to moderate temperatures and make them favorable for species that cannot tolerate warm water temperatures, including introduced salmonids.

Wetlands

Wetlands are common in this ecological landscape, with more than 248,000 acres of wetland identified and classified by the Wisconsin Wetlands Inventory (WDNR 2010). With a total area of nearly 1,755,000 acres, the Central Lake Michigan Coastal Ecological Landscape is 14% wetland. Nearly 174,000 acres are forested wetlands, over 38,000 acres are emergent/wet meadow, and nearly 35,000 acres are scrub/shrub wetlands. Highest wetland concentrations occur along the west shore of Green Bay, and in estuaries and embayments near Lake Michigan. Extensive floodplain forests are associated with the larger rivers and streams, such as the Wolf and Embarrass rivers, but these are not as extensive as those along major rivers floodplains in southwestern Wisconsin, such as the Mississippi, lower Wisconsin, Chippewa, and Black rivers.

In Green Bay, water level fluctuations are cyclical and occur on a daily, seasonal, and decadal basis. Lake Michigan water level fluctuations caused by short-term seiches considerably alter the extent of wetlands in lower Green Bay, particularly

Deer Creek Wildlife Area, Tamarack Swamp. Note small clearcut lower right in upland forest. Photo by Eric Epstein, Wisconsin DNR.

Wild rice. Mosquito Hill oxbow, Wolf River. Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

those on the west shore. Fluctuations of Fox River water levels allow nutrient- and silt-laden water to inundate the lower Green Bay marshes. The more pronounced changes in Green Bay water levels occur at intervals of 10–20 years. In the past, marsh vegetation in at least some parts of the bay was reduced by as much as 90% during periods of high water (Bosley 1978, Frieswyk and Zedler 2007). In 1986 water levels reached a historic high. During the period from 1997 to 2001, water levels dropped by 1.25 meters and reached a historic low. It was at this time of low water that several invasive plants "exploded," especially common reed, narrow-leaved cat-tail (*Typha angustifolia*), and hybrid cat-tail (*Typha* x *glauca*), and became the overwhelmingly dominant species in the west shore marshes, especially in lower Green Bay (Frieswyk and Zedler 2007).

The extensive wetlands on the west shore of Green Bay provide important breeding and migratory stopover areas for waterbirds, spawning areas for fish, and support populations of rare plants and animals, including invertebrates. Peats Lake and Duck Creek (also called Atkinson Marsh Complex) are located near the southern end of Green Bay, west of the mouth of the Fox River and on either side of the mouth of Duck Creek. These shallow water wetlands in lower Green Bay are characterized by stands of emergent aquatic macrophytes. The exotic common reed grass has formed large monotypic clones here and dominates much of the area. Conditions in this marsh vary and many portions have been extensively ditched, diked, and filled, degrading the site and reducing its acreage and functional values. Pollution and siltation have degraded the Atkinson wetland complex that was historically one of the finest and largest wetlands in the Midwest (WDNR 2002). Urbanization continues to threaten the site, and the marsh is likely to suffer further degradation. Over 250 bird species have been recorded here, including colonial waterbirds and rare marsh birds, and this marsh continues to receive heavy use as a resting and staging area during migration. It is also a valuable spawning area for species such as northern pike. However, the simplification of the vegetative composition of the marsh has reduced habitat diversity, thus reducing the numbers of birds using the area for breeding and foraging (Epstein et al. 2002b).

Privately owned wetlands in lower Green Bay are subject to relatively high development pressure for conversion to agricultural or residential uses. The hydrology of this area has been drastically altered by the construction of homes during past periods of low water in Lake Michigan. Wetlands in and around the Sensiba Wildlife Area just north of the city of Green Bay have been highly altered by ditch, dike, road, and home construction.

On the Lake Michigan side of the southern Door Peninsula, water levels rise and fall, but these short-term fluctuations are not as pronounced as those that occur in Green Bay during major seiche events (see the "Lake Michigan" section, above) or storms. The extent and habitat value of unusual and ecologically valuable shoreline habitats such as sand, cobble, and bedrock beaches, as well as periodically inundated coastal wetlands, can vary dramatically with these long-term changes in water levels.

There were no recorded wild rice waters within this ecological landscape until a vigorous stand (of unknown origin) was noted in a Wolf River backwater in 2001 by Wisconsin DNR biologists E. Epstein and E. Spencer.

Water Quality

■ **Surface Water Quality.** A number of rivers and streams here originate in wetland settings that provide good to excellent water quality in the headwaters. Downstream reaches tend to be influenced by agricultural and urban land uses, while a few have received past industrial contamination, often resulting in fair or poor water quality conditions. Streams in the Sheboygan River basin have been evaluated based on a number of water chemistry, habitat, and biological community parameters to investigate water quality conditions and needed improvements under the federal Clean Water Act. Many other streams have been described in Wisconsin DNR watershed narratives (see Appendix 8.A at the end of this chapter). These water quality evaluations and narrative summaries indicate that nonpoint source water quality problems exist in several watersheds here, especially in heavily agricultural areas.

Outstanding Resource Waters (ORW) or ***Exceptional Resource Waters*** (ERW) are surface waters that have good water quality, support valuable fisheries and wildlife habitat, provide outstanding recreational opportunities, and are not significantly impacted by human activities. Waters with ORW or ERW status warrant additional protection from the effects of pollution. Both designations have regulatory restrictions, with ORWs being the most restricted. These designations are intended to meet federal Clean Water Act obligations and prevent any lowering of water quality or degradation of aquatic habitats in these waters. They are also used to inform and guide land use changes and human activities near these waters. Two streams are designated as Outstanding Resource Waters, and seven are designated as Exceptional Resource Waters in the Central Lake Michigan Coastal Ecological Landscape. These streams are the Little Wolf, Branch, East Twin, and Embarrass rivers, and Whitcomb, Keyes, Beaver, Little Scarboro, and Casco creeks. A complete list of ORW and ERW in this ecological landscape can be found on the Wisconsin DNR website (WDNR 2013b).

Waters designated as impaired on the ***U.S. Environmental Protection Agency (EPA) 303(d) list*** exhibit various water quality problems including ***polychlorinated biphenyls (PCBs)*** in fish, sediments contaminated with industrial metals, mercury from atmospheric deposition, bacteria from farm and urban runoff, and habitat degradation. Since the 303(d) designation is narrowly based on the criteria above, a waterbody could be listed as a 303(d) water as well as an ORW or ERW. These designations are not mutually exclusive. A plan is required by the U.S. Environmental Protection Agency on how 303(d) designated waters will be improved by the Wisconsin DNR. This designation is used as the basis for obtaining federal funding, planning aquatic management work, and meeting federal water quality regulations. Numerous streams in this ecological landscape are 303(d) impaired waters. For example, in the Sheboygan River basin, 7.5% of the total stream miles do not meet water quality standards on a consistent basis. Among the rivers and streams that are impaired are various segments of the Manitowoc, Branch, West Twin, Kewaunee, Sheboygan, Wolf, East, and Fox rivers along with Duck, Apple, Plum, Otter, Bear, Indian, Trout, and Kankapot creeks. Low oxygen levels, excessive sedimentation, and contamination by PCBs and mercury are the major water use impairments found in these waters. Some of these, such as the contaminants, have resulted in fish consumption advisories. The complete EPA 303(d) list of impaired waters and criteria can be viewed at the Wisconsin DNR impaired waters web page (WDNR 2013a).

Lakes exhibit a variety of water quality conditions, but in this ecological landscape they tend to be eutrophic due to land use influences, including shoreline development, septic systems, and agricultural and other nonpoint runoff. There are no designated high water quality lakes here. Lake Michigan and Green Bay as well as six inland lakes (Silver, East Alaska, Pine, Grass, Round, and Bullhead lakes) have been designated as 303(d) impaired waters. Contaminants, low oxygen levels, and excessive sedimentation are the major water quality impairments found in these waters. Atmospheric mercury deposition is the most common cause of water quality impairment that meets the 303(d) criteria for listing, followed by PCBs in sediments, and excessive phosphorus. The nearshore areas of Lake Michigan are impaired by coliform bacteria (*Escherichia coli*), often from agricultural runoff or similar sources.

As an indication of the relative severity of water quality problems in the Central Lake Michigan Coastal Ecological Landscape, the federal Natural Resources Conservation Service has rated the Manitowoc-Sheboygan Watershed at 13.1 on a scale of zero (lowest conservation need) to 24.2 (highest conservation need; USDA NRCS 2008). The major resource concerns center around excessive nutrients and organic compounds in surface and ground waters. Surface and ground waters are being degraded from agricultural and residential land uses within the watershed. Management and restoration of forest and wetland habitats are the major water quality improvement priorities for this watershed.

The Wolf River receives discharges from the city of New London, the village of Shiocton, and the Borden Consumer Products Division. All are in substantial compliance with their Wisconsin Pollutant Discharge Elimination System (WPDES) permits, but it is unknown whether the cooling wastewater discharge from Borden is impacting the Wolf River. Other pollution sources along the Wolf River are nonpoint in nature, primarily animal wastes and cropland runoff. A mercury consumption advisory exists for walleye greater than 15 inches for the Wolf River from below Shawano downstream to Highway 156.

The lower Little Wolf River was ranked by the Winnebago Comprehensive Management Plan as a medium priority nonpoint source planning watershed due to local soil erosion and animal waste problems. Available data indicate that problems related to these nonpoint source pollutants do exist, but their impacts do not seem to be severe.

Winnebago County ranked the Embarrass River watershed as a high priority for nonpoint source grant funding for remediation and restoration, due to critical animal waste and soil erosion problems. Severe nonpoint source problems exist, with heavy soil losses, impaired fisheries, excess aquatic vegetation, and dissolved oxygen violations.

From the latter part of the 19th century through the first half of the 20th century, lower Green Bay was heavily impacted by industrial and municipal wastewater discharges and other pollutants, much of it entering the bay via the Fox River at the city of Green Bay. With 24 paper mills along 39 stream miles, the Fox River is home to the highest concentration of pulp and paper mills in the world (Katers 2009). Municipal sewage plants and industries prominent in the lower Fox River valley and the city of Green Bay discharged large quantities of wastes directly into Green Bay for many decades (WDNR 1993a).

The impact of historical water pollution affecting human health, aesthetics, and biodiversity was one of the prime drivers behind the state and federal water pollution control laws and programs of the late 1960s and 1970s. The concentrations and extent of these contaminants led the ***International Joint Commission*** to designate the lower Fox River and lower Green Bay as well as the lower Sheboygan River as Great Lakes Areas of Concern (AOC). However, lesser concentrations of sediment contamination occur throughout the rest of Green Bay within this ecological landscape. See the "Land Use Impacts" section of this chapter for more information on AOCs in this ecological landscape.

Groundwater Quality. Much of the eastern portion of Wisconsin, including the Central Lake Michigan Coastal Ecological Landscape, is characterized by karst topography. Karst topography is created by the dissolution of layers of soluble bedrock, usually carbonate rock such as limestone or dolomite. The Niagara escarpment is the dominant geologic feature of this ecological landscape and is composed of dolomite with vertical and horizontal fractures, which includes many caves, sinkholes, disappearing streams, and springs.

Where karst topography is covered with little or no soil, there is rapid surface water infiltration into the groundwater aquifer with limited filtration of surface contaminants. Therefore, this ecological landscape is subject to frequent and persistent groundwater contamination from natural events and human land use practices. Bacterial contamination and high nitrates are continuing problems in portions of Brown, Door, Calumet, Kewaunee, and Manitowoc counties. Problems can result from large animal feedlots and manure spreading practices, failing septic systems, spreading of industrial wastes, and urban and rural runoff. The result is contamination of the groundwater including the wells that get water from these dolomite formations.

Special well casing construction requirements have been established for some areas in northeast Wisconsin where surface waters have contaminated the drinking water aquifer. These requirements add significantly to the cost of well construction, and public moneys have been used to replace ***private wells*** contaminated with manure and other surface contaminants. Because of the shallow soils and fractured bedrock, problems are likely to occur in the future, resulting in additional areas designated with special well casing construction requirements. There will continue to be potential for severe health consequences due to contaminated drinking water and additional expenditures of public money to remediate groundwater contamination.

Another notable groundwater problem occurs in this ecological landscape due to high levels of arsenic in the groundwater. A 2002 joint Wisconsin DNR-Wisconsin Geological and Natural History Survey study revealed that a primary cause of elevated arsenic levels in the lower Fox River valley is the drawdown of groundwater by pumping. This exposes arsenic-bearing minerals in the aquifer to oxygen, which causes a chemical reaction making the arsenic water-soluble. Arsenic concentrations are especially severe in the lower Fox River valley. In parts of Brown, Outagamie, Shawano, and Winnebago counties, 20% of drinking water supplies exceed the federal drinking water standard of 10 parts per billion (ppb) for arsenic (UWWRI 2012). Long-term exposure to arsenic may lead to increased risks of certain cancers as well as neurological damage, hypertension, and other health impacts. As a result, the state established a Special Well Casing Depth Area in portions of Outagamie and Winnebago counties in 2004 where certain well construction methods are required to minimize the likelihood of arsenic contamination of well water.

If wastewater treatment does not remove arsenic from contaminated well water, then contamination of surface water by wastewater discharges containing arsenic could be a cause for concern. Ongoing efforts include expanding the understanding of health effects to people exposed to high levels of arsenic in drinking water, improving public information on groundwater arsenic, and encouraging more widespread testing of drinking water supplies for the presence of arsenic. Researchers are seeking more efficient and more cost effective ways to treat water as well as to detect and treat wells exhibiting arsenic contamination.

Biotic Environment

Vegetation and Land Cover

Historical Vegetation

Several sources were used to characterize the ***historical vegetation*** of the Central Lake Michigan Coastal Ecological Landscape, relying heavily on data from the federal General Land Office's public land survey (PLS) conducted in Wisconsin between 1832 and 1866 (Schulte and Mladenoff 2001). PLS data are useful for providing estimates of forest composition and tree species dominance for large areas (Manies and Mladenoff 2000). Finley's map of historical land cover based on his interpretation of PLS data was also consulted (Finley 1976). Additional inferences about vegetative cover were sometimes drawn from information on land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives. More information about these data sources is available in Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials."

According to Finley's map and data interpretation (Finley 1976), in the mid-1800s this ecological landscape was dominated by northern or central hardwood forests, interspersed with a mixture of wetlands, and minor inclusions of other vegetative cover. Northern or central hardwoods, oak (*Quercus* spp.), and wetland forests covered 96% of the area (Figure 8.4). Wetlands (including forested wetlands) covered approximately 18% of the area (see the map "Vegetation of Wisconsin in the Mid-1800s" in Appendix G, "Statewide Maps," in Part 3).

Public land survey information has been converted to a database format, and relative importance values (RIV) for tree species were calculated based on the average of tree species density and ***basal area*** (He et al. 2000). This analysis indicates that American beech (20.3% of RIV) and sugar maple (12.7%) were the only species with an RIV of greater than 10%. There were five species with an RIV of at least 5%: eastern hemlock (8.4%), eastern white pine (7.2%), black ash (7.1%), elm (6.3%), and white oak (*Quercus alba*) (6.1%). See the map "Vegetation of the Central Lake Michigan Coastal Ecological Landscape in the Mid-1800s" in Appendix 8.K at the end of this chapter for a spatial representation of these data.

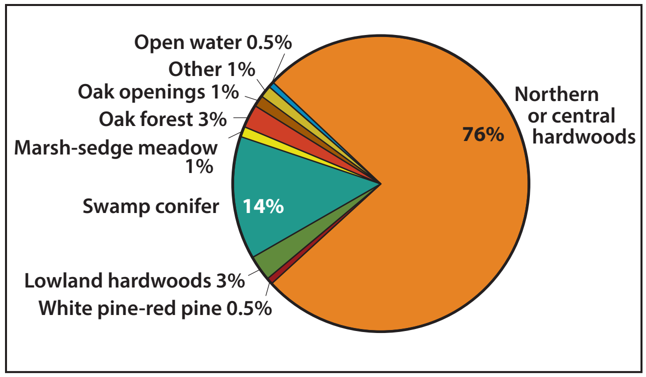


Figure 8.4. *Vegetation of the Central Lake Michigan Coastal Ecological Landscape during the mid-1800s, as interpreted by Finley (1976) from federal General Land Office public land survey information.*

Current Vegetation

There are several data sets available to help assess current vegetation on a broad scale in Wisconsin. Each was developed for different purposes and has its own strengths and limitations in describing vegetation. For the most part, WISCLAND (Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data), the Wisconsin Wetlands Inventory (WWI), the U.S. Forest Service's Forest Inventory and Analysis (FIA), and the National Land Cover Database (NLCD) were used. Results among these data sets often differ because they are the products of different methodologies for classifying land cover, and each data set was compiled based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales. In general, information was cited from the data sets deemed most appropriate for the specific factor being discussed. Information on data source methodologies, strengths, and limitations is provided in Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials."

The Central Lake Michigan Coastal Ecological Landscape is just over 1,755,000 acres in size, of which approximately 14% is forested (WDNR 1993b). WISCLAND land use/land cover data from 1992 indicates that 69% of the ecological landscape was in agricultural use (Figure 8.5). By percentage, only the Southwest Savanna Ecological Landscape has more land in agricultural usage. However, when looking at the combined total of agricultural and urban use, the Central Lake Michigan Coastal Ecological has the highest percentage of these two combined of any ecological landscape (73%).

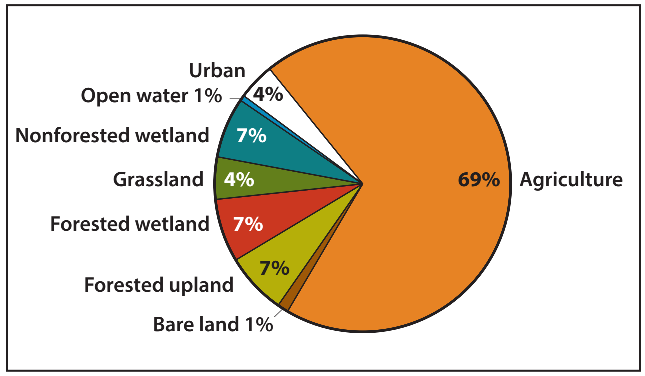


Figure 8.5. *WISCLAND land use/land cover data showing categories of land use classified from 1992 LANDSAT satellite imagery for the Central Lake Michigan Coastal Ecological Landscape (WDNR 1993b).*

The Wisconsin Wetlands Inventory offers a more specific assessment of wetlands than is available with WISCLAND data but is limited to those areas identified from satellite imagery as wetland. According to the Wisconsin Wetlands Inventory (WDNR 2010), wetlands occupy a relatively large portion of the Central Lake Michigan Coastal Ecological Landscape, comprising 14.1% (approximately 248,000 acres) of this ecological landscape's vegetation. Forested wetlands are the most abundant, covering more than 173,000 acres, followed by emergent/wet meadow, covering approximately 38,000 acres of the ecological landscape. Shrub/scrub wetlands occur on approximately 34,000 acres.

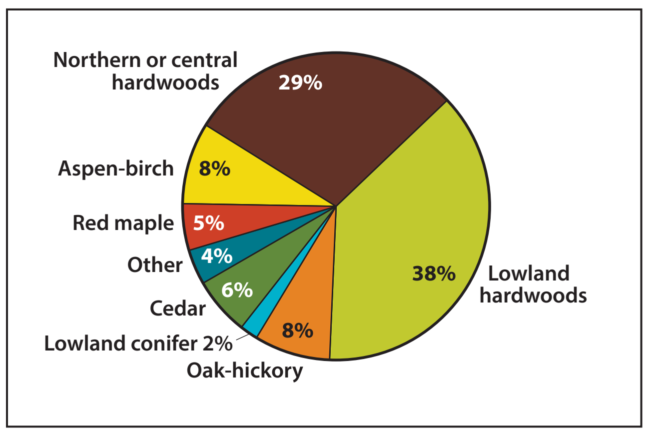


Figure 8.6. *Forest Inventory and Analysis data (USFS 2004) showing forest types as a percentage of forested land area (greater than 17% canopy cover) for the Central Lake Michigan Coastal Ecological Landscape. The "cedar" category is northern white-cedar. The "wetland conifer" category may also include some northern white-cedar because it is found in both upland and wetland sites here. See Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials," for more information about the FIA data.*

Additional information on wetlands and wetland flora may be found in the "Natural Communities" and "Flora" sections of this chapter and in Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin." Some of the important animals associated with wetlands are discussed in the "Fauna" section of this chapter.

Forest Inventory and Analysis (FIA) data, which were point samples on forested lands, were compiled to assess the timber resources of the country(USFS 2004). This database contains more information on forest types and species compositions, which can be generalized across the ecological landscapes and offers more specific information about forested lands than WISCLAND. Because FIA data are derived from on the ground sampling as opposed to satellite imagery, the numbers may offer a different interpretation of forests than WISCLAND. According to FIA data summarized in 2004 (USFS 2004), approximately 83% of land area in the Central Lake Michigan Coastal Ecological Landscape is nonforested, and about 17% is forested. The predominant forest ***cover type*** group is lowland hardwoods (38% of the forested area), followed by northern or central hardwoods (29% of the forested area). All other forest types occupy less than 10% of the forested land area (Figure 8.6).

Changes in Vegetation over Time

The purpose of examining historical conditions is to identify ecosystem factors that formerly sustained species and communities that are now altered in number, size, or extent or that have been changed functionally (for example, by constructing dams or suppressing fires). Although data are limited to a specific snapshot in time (noting that some "snapshots" are far more revealing than others), they provide valuable insights into Wisconsin's ecological history and capabilities. Maintaining or restoring some lands to more closely resemble historical systems and including some structural or compositional components of the historical landscape within actively managed lands can help conserve important elements of biological diversity. We do not mean to imply that entire ecological landscapes should be restored to historical conditions as this is neither possible nor desirable within the context of providing for human needs and desires. Information on the methodology, strengths, and limitations of the vegetation change data is provided in Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials."

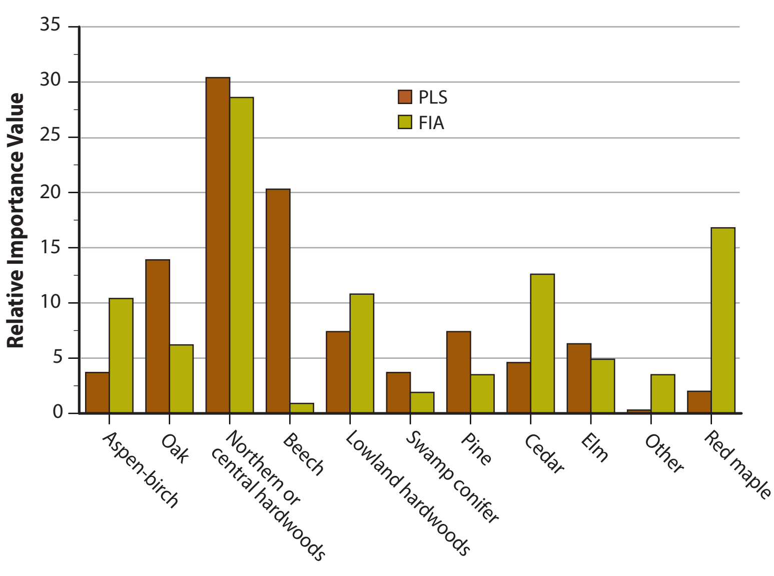


Figure 8.7. *Comparison of tree species' relative importance value (average of relative dominance and relative density) for the Central Lake Michigan Coastal Ecological Landscape during the mid-1800s, when the federal General Land Office's public land survey (PLS) data were collected, with 2004 estimates from Forest Inventory and Analysis (FIA) data. Each bar represents the proportion of that forest type in the data set (totals equal 100). Trees of less than 6-inch diameter were excluded from the FIA data set to make it more comparable with PLS data. See Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials," for more information about the PLS and FIA data.*

The overwhelming change to the native vegetation of the Central Lake Michigan Coastal Ecological Landscape has been the striking loss of forest cover. Historically, almost all of this ecological landscape supported mesic forest. Now, only a small percentage (14% versus 96% historically) remains in forest cover. In addition, much of the remaining forest is of lowland types, with northern white-cedar and black ash among the important lowland forest canopy dominants.

Besides the loss of forest cover, other significant vegetation changes have occurred because of hydrological disruption, fragmentation and isolation of remnant forests and open wetlands, grazing, and an increase in nonnative plants at the expense of native vegetation (this has been especially noticeable in the marshes of lower Green Bay where common reed is now a dominant plant and in wet meadows, which in many areas are now monotypes of reed canary grass). Dutch elm disease has killed most of the large elms here, as elsewhere in the state, and other plant diseases have also impacted native vegetation.

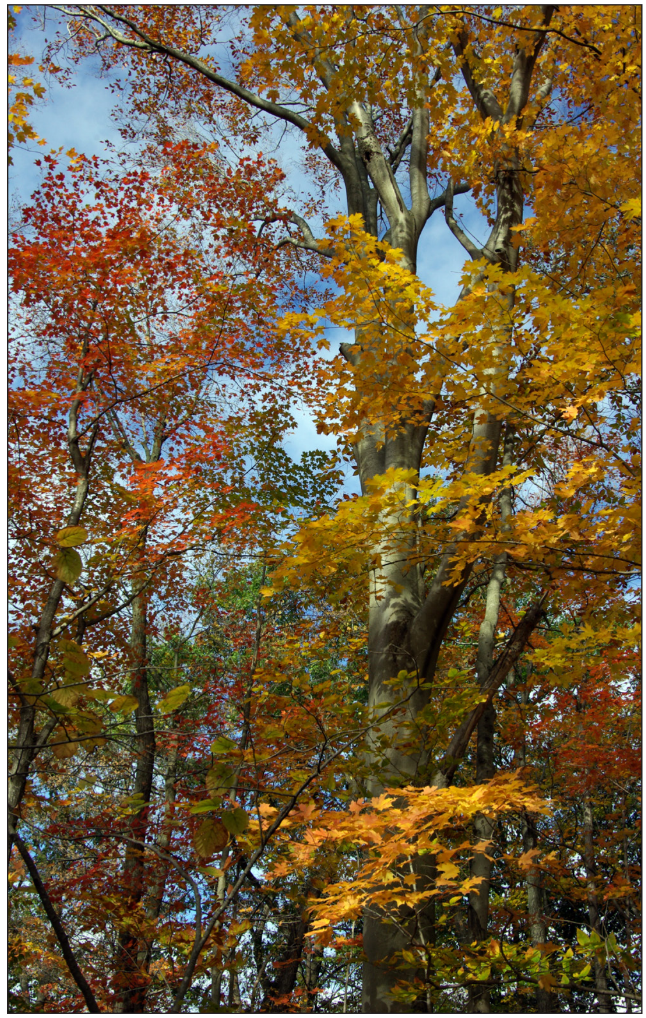
Current forest vegetation (based on FIA) is a mix of northern hardwood species including sugar maple, American basswood, white ash and others (29.5% of RIV) such as red maple (16.8%), northern white-cedar (12.6%); lowland hardwood species including black ash, swamp white oak, and eastern cottonwood (*Populus deltoides*) (10.8%); and aspen-birch (10.4%) (Figure 8.7). American beech has been reduced dramatically from historical levels (from 20.3% to 0.9% of RIV), while red maple has increased more than eight times (from 2.0% to 16.8% of RIV). Northern white-cedar has also increased (from 4.6% to 12.6% of RIV), as have lowland hardwood species (from 7.4% to 10.8% of RIV). The increase of relative importance for northern white-cedar and lowland hardwoods is the result of the extensive clearing of mesic northern or central hardwood forests for agriculture following Euro-American settlement while the lowland forests were generally not converted to agricultural use. So while the absolute amount of lowland forest cover has decreased, this decrease has been much less than for the upland types, raising their relative importance.

Natural Communities

This section summarizes the abundance and importance of major physiognomic (structural) natural community groups in the Central Lake Michigan Coastal Ecological Landscape. Some of the exceptional opportunities, needs, and actions associated with these groups or with some of the individual natural communities, are discussed briefly.

For details on the composition, structure, and distribution of the specific natural communities found in the Central Lake Michigan Coastal Ecological Landscape, see Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," in Part 1 of the book. Information on invasive species can be found in the "Natural and Human Disturbances" section of this chapter.

Forests. The vast majority of the Central Lake Michigan Coastal Ecological Landscape historically supported mesic forests dominated by sugar maple, American basswood, and American beech. Eastern white pine was an important component, though seldom a dominant, in some of these forests, and eastern hemlock was present but found mostly in cool, moist locations close to Lake Michigan. Much of the mesic forest has been cleared, and the land converted to agricultural and urban-industrial uses. Pine-dominated dry-mesic forests were limited to areas with sandy or very shallow soils, including the sandy ridges associated with the ridge-and-swale complexes found along the Lake Mighigan coast. Some of Wisconsin's oldest trees are the northern white-cedars and eastern red cedars (*Juniperus virginiana*) growing on the Niagara Escarpment in Brown County.



Remnant stand of mesic hardwood forest is composed of large sugar maple, American beech, American basswood, and nothern red oak. This forest community has been greatly reduced in the Central Lake Michigan Coastal Ecological Landscape. Ozaukee County. Photo by Thomas Meyer, Wisconsin DNR.

Extensive forested wetlands occur in several distinct environmental settings. The greatest acreage of Floodplain Forest in eastern Wisconsin borders the Wolf River from just below Shawano all the way downstream to the vicinity of Fremont. East and south of Green Bay, there are several large insular swamps, composed mostly of hardwoods (ashes, maples, elms) but with pockets of tamarack and/or northern white-cedar. The ridge-and-swale complexes along Lake Michigan include lowland forests dominated by conifers or mixtures of conifers and deciduous species. Stands of hardwood swamp are also present in some areas, for example, in wooded wetlands along the west side of lower Green Bay.

Savannas. Although the Central Lake Michigan Coastal Ecological Landscape lies north and east of the ***Tension Zone*** (Curtis 1959), small areas of oak savanna (Oak Openings) were recorded by early surveyors near the Wolf River, to the west of the Fox River just north of Lake Winnebago, and along southeastern Green Bay (Finley 1976). Some of the savannas in the southeastern Green Bay area may have been maintained by activities of indigenous peoples (Dorney and Dorney 1989). A few severely overgrown savanna remnants persist near the city of Green Bay, despite many decades of fire suppression, where the soils are poor and/or the bedrock is close to the surface.

The alvar vegetation near the village of Red Banks is structurally somewhat similar to oak savanna or woodland, with which it shares a few prairie components. But there are few other locations in Wisconsin at which one will see bur oak (*Quercus macrocarpa*) and northern white-cedar growing side by side, and the understory composition of these remnant alvars contains unusual species assemblages, which include a number of rare plants (for more information on Alvar, see Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin").

Shrub Communities. Shrub swamps are common on the margins of lakes and streams, and they also occur in partially drained lowlands that formerly supported sedge meadow or shallow marsh vegetation. Shrub-carr is the most common shrub-dominated wetland here, especially in the western portion of the ecological landscape and in the basins drained by some of the larger streams, but Alder Thicket is also present and widespread.

Herbaceous Communities. Extensive emergent marshes border large portions of lower Green Bay west of the Fox River mouth, though some of these are diked and have now lost their direct hydrological connection to the bay. In recent years, monotypes of the highly invasive common reed have replaced the more diverse marshes composed of cat-tails (*Typha* spp.), bulrushes (*Schoenoplectus* spp., *Scirpus* spp.), bur-reeds (*Sparganium* spp.), and arrowheads (*Sagittaria* spp.) that were historically prevalent in lower Green Bay. Large acreages of highly productive emergent marsh were filled at the mouth of the Fox River to accommodate industry and facilitate residential growth.

Large marshes still occur at the mouths of several of the larger rivers that flow into Lake Michigan. Examples occur on the lower Kewaunee River and on the East Twin and West Twin rivers at the city of Two Rivers. Cities have been sited at the mouths of many of the larger rivers entering Green Bay or Lake Michigan. Much of the wetland vegetation associated with the lower rivers was destroyed to accommodate urban-industrial developments.

That portion of the Wolf River flowing through the western part of the Central Lake Michigan Coastal Ecological Landscape is mostly forested but also includes shrub swamp and marsh vegetation (some of the latter has been created by impoundment construction and water level manipulation). The Wolf River system's most extensive marshes occur downstream on either side of Fremont within the Southeast Glacial Plains Ecological Landscape.

Sedge meadows occur in some of the wetter and more open swales along Lake Michigan at Point Beach, in some of the Wolf River wetlands, and along Green Bay's West Shore. Sedge-dominated wetlands are not particularly common or extensive in this ecological landscape.

Beach and dune vegetation is most abundant and best developed at Point Beach in Manitowoc County and at Kohler-Andrae Dunes in Sheboygan County. Heavy recreational use occurs at these locations, and this had caused severe erosion in some areas and facilitated the colonization and spread of invasive plants. However, these are some of the most extensive beach and dune communities along the entire western shore of Lake Michigan. Protection measures have included the direction of foot and vehicular traffic away from erosion-prone areas and construction of boardwalks. Plants and invertebrates endemic to the Great Lakes region are dependent on the long-term viability of these habitats.

Kewaunee Marsh, emergent marsh and estuary. Kewaunee County. Photo by Eric Epstein, Wisconsin DNR.

Open meadow of bluejoint grass and sedges along lower Molash Creek. Manitowoc County. Photo by Andy Clark, Wisconsin DNR.

Great Lakes beach and dune. The vegetation becomes increasingly complex from open unvegetated beach, to grassy foredune, shrub dune, and xeric conifer-hardwood forest. Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.

Portions of unusual plant community atop the Niagara Escarpment resemble an oak savanna, with a sparse canopy of bur oak and shagbark hickory over an herb-dominated ground layer. In other areas, plants with more northerly distributions and species found mostly on beaches or other shoreline environments are important. Red Banks Alvar State Natural Area, Brown County. Photo by Thomas Meyer, Wisconsin DNR.

The alvar communities near Red Banks support small open areas in which some prairie species occur, but these are sometimes mixed with plants more characteristic of beach habitats. The alvar assemblage is a unique mixture of floristic elements.

Aquatic Communities. See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for descriptions of aquatic communities.

Forest Habitat Types

The Central Lake Michigan Coastal Ecological Landscape is dominated by three habitat type groups: mesic, mesic to wet-mesic, and wet-mesic to wet (Table 8.1). Mesic sites typically are associated with loamy soils that are well to moderately well drained and nutrient rich. Forest stands can be dominated by any mixture of sugar maple, red maple, white ash (*Fraxinus americana*), American basswood, American beech, and aspen (*Populus* spp.). Common associates include northern red oak (*Quercus rubra*), white oak, black cherry (*Prunus serotina*), white birch (*Betula papyrifera*), and eastern white pine. Potential late-successional dominants are sugar maple and American beech, accompanied by white ash and American basswood.

Mesic to wet-mesic sites typically are associated with loamy soils that are somewhat poorly drained and nutrient rich to medium. Most forest stands are dominated by any mix of red maple, ashes, American basswood, swamp white oak, and aspen; associates often include sugar maple, elm, yellow birch (*Betula alleghaniensis*), and white birch.

Wet-mesic to wet forested lowlands typically occur on poorly drained peat and muck soils. On nutrient medium to rich sites, stands may be dominated by swamp hardwoods or swamp conifers.

Flora

The Central Lake Michigan Coastal Ecological Landscape is situated immediately to the north and east of the ecoclimatic Tension Zone (Curtis 1959). The flora includes "northern" and "southern" elements, although species associated with prairie and savanna vegetation are poorly represented here and occur much more frequently to the south and west. Hardwood forests were dominant in the uplands prior to Euro-American settlement, but conifers were important in the northern parts of the ecological landscape and in a narrow strip along the Lake Michigan shore.

Other important floristic elements are associated with (in some cases limited to) the Lake Michigan shoreline, where habitats such as beaches, dunes, interdunal wetlands, and clay bluffs support specialists of limited distribution. The Niagara Escarpment provides habitats for species that are adapted to

Table 8.1. *Forest habitat type groups and forest habitat types of the Central Lake Michigan Coastal Ecological Landscape (CLMC).*

Southern forest habitat type groups common within CLMC EL[b]	Southern forest habitat types[a] common within CLMC EL[b]	Southern forest habitat types minor within CLMC EL[b]
Mesic (M)	AFH AFAs AFAs-O	 ATFD AH
Wet-mesic to wet (WM-W)	Forest Lowland (habitat types not defined)	
Mesic to wet-mesic (M-WM)	Undefined wet-mesic (habitat types not defined)	

Source: Kotar and Burger 1996.

[a]Forest habitat types are explained in Appendix 8.B ("Forest Habitat Types in the Central Lake Michigan Coastal Ecological Landscape") at the end of this chapter.

[b]Groups listed in order from most to least common:
Common occurrence is an estimated 10–50% of forested land area.
Minor occurrence is an estimated 1–9% of forested land area.
Present: Other habitat types can occur locally, but each represents < 1% of the forested land area of the ecological landscape.

bedrock exposures. Wetlands, such as marshes, sedge meadows, hardwood swamps, and conifer swamps, contain plants of both northern and southern distribution.

The Wisconsin Natural Heritage Inventory tracks 45 species of vascular plants that have been documented in the Central Lake Michigan Coastal Ecological Landscape and are considered rare (as of November 2009; WDNR 2009). Of these 45 species, 5 are Wisconsin Endangered, 12 are Wisconsin Threatened, and 28 are Wisconsin Special Concern. See Appendix 8.C at the end of this chapter for a complete list of the vascular plants found in the Central Lake Michigan Coastal in 2009 and tracked by the Natural Heritage Inventory, along with their legal status (if any), state and global ranks, total number of populations documented in Wisconsin, and the number of populations known from this ecological landscape.

Two of the species listed as Wisconsin Threatened, dwarf lake iris and dune thistle (Pitcher's thistle) (*Cirsium pitcheri*), are also listed as threatened species by the federal government. Both the dwarf lake iris and dune thistle are Great Lakes endemics and are found only in environments associated with Great Lakes shorelines.

Four of the rare plants known from this ecological landscape have been found nowhere else in Wisconsin: prairie dunewort (*Botrychium campestre*), harbinger-of-spring (*Erigenia bulbosa*), clustered broomrape (*Orobanche fasciculata*), and sand dune willow (*Salix cordata*). Prairie dunewort, harbinger-of-spring, and sand dune willow are each listed as Wisconsin Endangered. Prairie dunewort is considered globally rare. Clustered broomrape is listed as Wisconsin Threatened.

An additional four species have 50% or more, but not all, of their documented Wisconsin populations here: American sea-rocket (*Cakile lacustris*), sand reedgrass (*Calamovilfa longifolia* var. *magna*), handsome sedge (*Carex formosa*), and Christmas fern (*Polystichum acrostichoides*). Sand reedgrass and handsome sedge are listed as Wisconsin Threatened. American sea-rocket and Christmas fern are Wisconsin Special Concern species.

Six of the 45 tracked plant species are globally rare: prairie dunewort (mentioned above, as it is known from no other ecological landscape in Wisconsin), the Great Lakes endemics dwarf lake iris and dune thistle (Pitcher's thistle), sweet-scented Indian-plantain (*Cacalia suaveolens*), and Laurentian bladder fern (*Cystopteris laurentiana*).

Thickspike (*Elymus lanceolatus* ssp. *psammophilus*), seaside spurge (*Euphorbia polygonifolia*), giant pinedrops (*Pterospora andromedea*), and long-spur violet (*Viola rostrata*) are other plant species considered important here because of the high state ranks assigned to them by Wisconsin botanists and because 20%–50% of their known Wisconsin populations occur in this ecological landscape.

Rich mesic hardwood forests of maple-beech and maple-basswood have been greatly reduced in abundance here because most of the land has been converted to agricultural, residential, and industrial uses. Remnants are almost all small

Significant Flora in the Central Lake Michigan Coastal Ecological Landscape

- Beach and dune habitats along Lake Michigan support highly specialized plant species, including rarities.
- Several plants endemic to Great Lakes shorelines are present along Lake Michigan, including dwarf lake iris and dune thistle (Pitcher's thistle).
- Interdunal wetlands support rare plant species.
- Rare plants associated with other Great Lakes shoreline habitats also occur here.
- The Niagara Escarpment is exposed as cliffs and ***talus slopes***, and these provide unique microhabitats that support rare biota and Wisconsin's oldest trees.
- Rich mesic hardwood forests support rare forest herbs such as snow trillium and foamflower. Intact forest remnants are now rare here.

Dune thistle (U.S. Threatened, Wisconsin Threatened) is a highly specialized plant endemic to dune habitats along the Great Lakes shores. Photo by Thomas Meyer, Wisconsin DNR.

Clustered broomrape (Wisconsin Threatened) is a root parasite and habitat specialist in dunes along Lake Michigan. Photo by R.C. Moran.

The snow trillium (Wisconsin Threatened) occurs in rich mesic hardwood forests. Photo by Armund Bartz, Wisconsin DNR.

and isolated, with histories of logging and grazing. Invasive plants and invertebrates, e.g., exotic earthworms (family Lumbricidae), gypsy moth (*Lymantria dispar*), and emerald ash borer (*Agrilus planipennis*), all have the potential to seriously impair the ability of some native plants to maintain viable populations in this ecological landscape's forests. Among the rare herbs documented here in recent years are foamflower (*Tiarella cordifolia*), harbinger-of-spring, and snow trillium (*Trillium nivale*).

Updated and expanded surveys to locate and identify intact natural communities and other habitats known to harbor or suspected of harboring rare plants are needed in many parts of this ecological landscape. Scattered habitats that should be considered for additional botanical survey attention include mesic hardwood forests, hardwood swamps, conifer swamps, ephemeral ponds, and portions of the Niagara Escarpment, which has unique microhabitats such as alkaline seeps and springs and xeric cliffs and blufftops.

This is a highly disturbed ecological landscape in which many natural habitats, including some that were formerly widespread and abundant such as mesic hardwood forests, have been seriously diminished and the remnants significantly fragmented and often altered. Invasive plants and invertebrates are already well established in certain habitats, and some recently arrived exotics may have the potential to spread rapidly.

Fauna

Changes in Wildlife over Time

Many wildlife populations have changed dramatically since humans arrived on the landscape, but these changes were not well documented before the mid-1800s. This section discusses only those wildlife species documented as having occurred in the Central Lake Michigan Coastal Ecological Landscape. Of those, this review is limited to species that were known or thought to be especially important here in comparison to other ecological landscapes. For a more complete review of historical wildlife in the state, see Chapter 4, "Changes and Trends in Ecosystems and Landscape Features," and a collection of articles written by A.W. Schorger, compiled into the volume *Wildlife in Early Wisconsin: A Collection of Works by A.W. Schorger* (Brockman and Dow 1982).

Historically the Central Lake Michigan Coastal Ecological Landscape was primarily a maple-basswood-beech forest interspersed with forested and nonforested wetlands. Because of its location along the Tension Zone at the transition between southern and northern Wisconsin, it had a mixture of southern and northern wildlife, including white-tailed deer (*Odocoileus virginianus*), gray wolf (*Canis lupus*), American black bear (*Ursus americanus*), American beaver, North American river otter (*Lontra canadensis*), Passenger Pigeon (*Ectopistes migratorius*), and Wild Turkey (*Meleagris gallopavo*). In the mid-19th century, the ecological landscape was settled by Euro-Americans, forests were cleared for agriculture, cities were established, and wildlife populations changed.

White-tailed deer were found throughout the state and were likely more abundant in southern Wisconsin than in the northern part of the state at the time of Euro-American settlement (Schorger 1953). White-tailed deer were reported as plentiful in this ecological landscape until around 1890. However, as Euro-American settlers arrived in Wisconsin, they depended on venison for food, and professional market hunters sent tons of venison to the eastern large cities. It was stated in the Green Bay newspaper in 1873 that venison was so cheap it did not cover the cost of the ammunition. Subsistence harvest, together with market hunting, reduced the state's white-tailed deer population to its lowest level late in the 19th century. White-tailed deer populations were low, and white-tailed deer were considered uncommon throughout southern Wisconsin from 1900 through the 1960s. However, since the early 1980s, white-tailed deer populations increased dramatically in this area (Figure 8.8), and deer are now abundant. Today white-tailed deer are important animals for wildlife watching and recreational hunting, but they also damage crops and native vegetation, suppress forest regeneration, and cause vehicle accidents.

The gray wolf was commonly found here, but declined after Euro-American settlement. The gray wolf declined gradually throughout the state from south to north due to loss of food sources, shooting, trapping, and poisoning (Schorger 1942a). Little gray wolf activity has been recorded recently in the Central Lake Michigan Coastal Ecological Landscape.

Historically, American black bears were found throughout the ecological landscape (Schorger 1949). However, by the late 1800s, American black bears became increasingly rare here due to habitat changes and unregulated hunting and trapping. American black bears are occasionally sighted in the northern part of this ecological landscape today.

The American beaver was present historically along the streams, rivers, and inland lakes of the Central Lake Michigan Coastal Ecological Landscape but likely declined quickly in the late 1700s as the fur trade and human settlement increased. Green Bay was a premier fur trading and shipping center in Wisconsin. Three to six hundred "packs" of furs were shipped each year in the mid-1700s (approximately 25,000–50,000 hides) from Green Bay (Schorger 1965). By the early 1800s, only a few hides were still being shipped from Green Bay. Today the American beaver occupies some of the rivers and inland lakes of the Central Lake Michigan Coastal where suitable habitat exists.

The North American river otter was present here but may not have been as abundant as in other parts of the state. The North American river otter typically inhabited streams, rivers, and inland lakes, but large lakes like Lake Michigan were less attractive (Schorger 1970). North American river otter numbers undoubtedly declined as did American beaver numbers as the fur trade and trapping pressure increased in the late 1700s. North American river otter and American beaver pelts were being traded and sold in Green Bay until 1836, but the origin of the pelts is unknown. The North American river otter is still present in the ecological landscape today along rivers and streams with suitable fish populations and habitat.

Although the distribution of the Passenger Pigeon has been described as covering the eastern half of North America (Schorger 1946), its nesting was limited by the presence and abundance of mast (primarily beechnuts and acorns). Schorger (1946) reported from newspaper accounts and interviews that the Passenger Pigeon nested by the millions in Wisconsin. Although central Wisconsin was the prime nesting area for the Passenger Pigeon, it undoubtedly nested in this ecological landscape as well, since one of its favorite foods, beechnuts, was common here. Since beechnuts were abundant in the fall of odd numbered years, Passenger Pigeons nested in large numbers in the spring of even numbered years (Schorger 1942a). In 1895 Passenger Pigeons were reported as quite plentiful at Manitowoc (Schorger 1946). Indiscriminate hunting and trapping on the nesting grounds

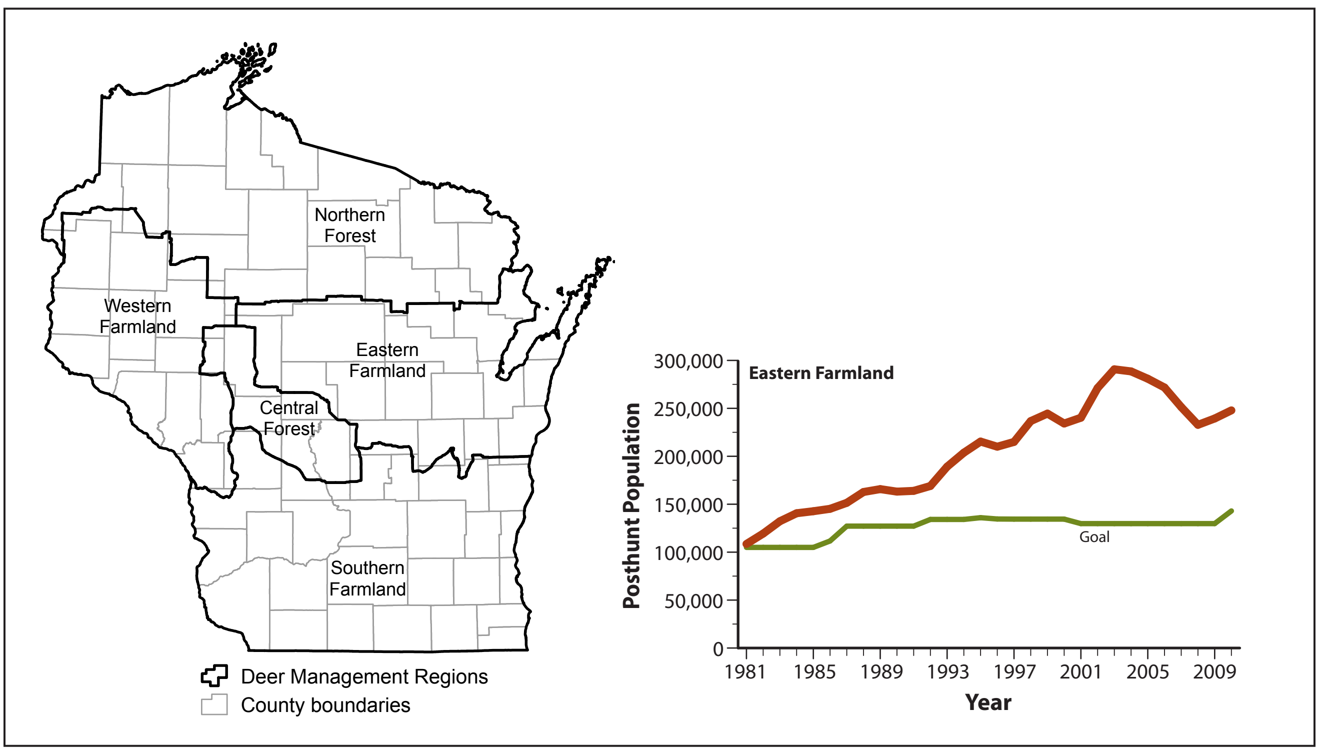


Figure 8.8. *White-tailed deer population size in relation to population goal in the eastern farmland deer management region, 1981–2010.*

and sale of the Passenger Pigeon at city markets across the eastern part of the country caused the extinction of this species from the wild by 1899. See Chapter 10, "Central Sand Plains Ecological Landscape," for a more detailed discussion of the Passenger Pigeon.

The range of the Wild Turkey was in southern Wisconsin below a line from Green Bay to Prairie du Chien (Figure 8.9; Schorger 1942b). Wild Turkeys were abundant in this ecological landscape. Early settler Andew Vieau reported that he took wagonloads of Wild Turkeys, venison, and other game from Port Washington to Milwaukee for sale in 1838. Due to persistent hunting by settlers for food, habitat changes, and the severe winter of 1842-43, Wild Turkeys were rare in this ecological landscape by the late 1840s. The Wild Turkey is now reestablished in every ecological landscape in the state, including the Central Lake Michigan Coastal. Numbers have increased dramatically since the 1990s. Today the Wild Turkey is common to abundant throughout the ecological landscape. See the "Fauna" section in Chapter 22, "Western Coulees and Ridges Ecological Landscape," for a more thorough discussion of Wild Turkey reintroductions.

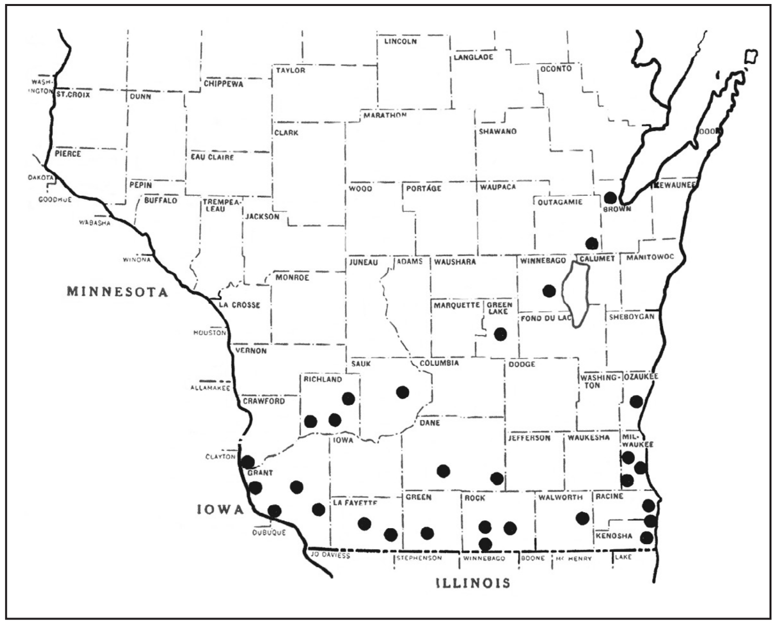


Figure 8.9. *Historical Wild Turkey range in Wisconsin. Figure printed with the written permission of The Wilson Ornithological Society, from Schorger, A.W. 1942. The Wild Turkey in early Wisconsin.* Wilson Bulletin *54:173–182.*

Introduction of the Ring-necked Pheasant (*Phasianus colchicus)* into this ecological landscape began in 1895 (Schorger 1947). The Two Rivers Gun club posted a notice in the spring of 1895 that their areas had been stocked. In 1895, the Wisconsin legislature passed a law making it illegal to "take, catch, or kill any Mongolian, Chinese, or English Pheasants, or any other variety of pheasants for a period of 5 years" to provide protection while establishing populations. Many early releases were unsuccessful, but the Ring-necked Pheasant eventually became established in this ecological landscape where it persists to this day.

The Gray Partridge (*Perdix perdix*) was introduced into the Central Lake Michigan Coastal Ecological Landscape in 1908 and was abundant for a period of years but has declined significantly in recent decades. Harvests have dropped by 95% since 1983 (Dhuey 2014). More intensive farming (e.g., early hay mowing, clean corn and grain harvesting methods, loss of winter cover) may be the reasons for this decline. This ecological landscape is still considered the primary Wisconsin range for this species, but it is not very common anywhere (Cutright et al. 2006).

Significant Wildlife

Wildlife are considered significant for an ecological landscape if (1) the ecological landscape is considered important for maintaining the species in the state and/or (2) the species provides important recreational, social, and economic benefits to the state. To ensure that all species are maintained in the state, "significant wildlife" includes both common species and species that are considered "rare" (in this book, "rare" includes species listed as endangered or threatened by either Wisconsin or the federal government or species that are listed as "special concern" by the State of Wisconsin). Four categories of species are discussed: rare species, Species of Greatest Conservation Need (SGCN), responsibility species, and socially important species (see definitions in text box). As managing wildlife communities and habitats are the most efficient way to benefit a majority of species, we discuss management of different wildlife habitats in which significant fauna occur.

■ **Rare Species.** As of November 2009 (WDNR 2009), the Wisconsin Natural Heritage Working List documented 131 rare species including 2 mammals, 34 birds, 7 herptiles, 12 fishes, and 76 invertebrates within the Central Lake Michigan Coastal Ecological Landscape (see Appendix 8.C for a comprehensive list of the rare animals known to exist in this ecological landscape in 2009). These include two U.S. Endangered, 12 Wisconsin Endangered, 21 Wisconsin Threatened, and 98 Wisconsin Special Concern species. See Appendix 8.D for the number of rare species per taxa group documented within the Central Lake Michigan Coastal Ecological Landscape.

■ **Federally Listed Species:** Three U.S. Endangered animals occur in this ecological landscape: the Karner blue butterfly (*Lycaeides melissa samuelis*), also listed as a Wisconsin Special Concern Species; the Hine's emerald dragonfly (*Somatochlora hineana*), also listed as Wisconsin Endangered; and the snuffbox mussel (*Epioblasma triquetra*), also listed as Wisconsin Endangered. The Bald Eagle (*Haliaeetus leucocephalus*) (formerly U.S. Threatened) is also found here. Since its delisting in 2007, the species remains federally protected under the federal Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act. The Bald Eagle is listed as a Wisconsin Special Concern species (WDNR 2009).

■ **Wisconsin Endangered Species:** No Wisconsin Endangered mammals occur in this ecological landscape. Seven Wisconsin Endangered birds occur here, including Snowy Egret (*Egretta thula*), Peregrine Falcon (*Falco peregrinus*), Loggerhead Shrike (*Lanius ludovicianus*), Barn Owl (*Tyto alba*), Caspian Tern (*Hydroprogne caspia*, listed on the Wisconsin Natural Heritage Working List as *Sterna caspia*), Forster's Tern (*Sterna forsteri*), and Common Tern (*Sterna hirundo*). Other Wisconsin Endangered species documented here include one herptile, northern cricket frog (*Acris crepitans*); one fish, striped shiner (*Luxilus chrysocephalus*); one mussel, snuffbox; and two other invertebrates, Hine's emerald dragonfly and Midwest Pleistocene vertigo snail (*Vertigo hubrichti*).

■ **Wisconsin Threatened Species:** No Wisconsin Threatened mammals occur in this ecological landscape. There are seven Wisconsin Threatened birds documented here, including Henslow's Sparrow (*Ammodramus henslowii*), Great Egret (*Ardea alba*), Red-shouldered Hawk (*Buteo lineatus*), Yellow Rail (*Coturnicops noveboracensis*), Cerulean Warbler (*Setophaga cerulea*, listed as *Dendroica cerulea* by the Wisconsin Natural Heritage Working List), Acadian Flycatcher (*Empidonax virescens*), and Hooded Warbler (*Setophaga citrina*, listed as *Wilsonia citrina* by the Wisconsin Natural Heritage Working List). Other Wisconsin Threatened species occurring in the Central Lake Michigan Coastal include three Wisconsin Threatened herptiles: wood turtle (*Glyptemys insculpta*), Blanding's turtle (*Emydoidea blandingii*), and Butler's gartersnake (*Thamnophis butleri*); four Wisconsin Threatened fish: longear sunfish (*Lepomis megalotis*), redfin shiner (*Lythrurus umbratilis*), greater redhorse (*Moxostoma valenciennesi*), and river redhorse (*Moxostoma carinatum*); five mussels: slippershell mussel (*Alasmidonta viridis*), monkeyface (*Quadrula metanevra*), salamander mussel (*Simpsonaias ambigua*), buckhorn (*Tritogonia verrucosa*), and ellipse (*Venustaconcha ellipsiformis*); and two additional invertebrates, pygmy snaketail (a dragonfly), and the cherrystone drop (a land snail) (*Hendersonia occulta*).

■ **Wisconsin Special Concern Species:** Wisconsin Special Concern species in the Central Lake Michigan Coastal Ecological Landscape include 2 mammals, 20 birds, 3 herptiles, 7 fishes, and 66 invertebrates (see Appendix 8.C for a complete list of Wisconsin Special Concern species).

■ **Species of Greatest Conservation Need.** Species of Greatest Conservation Need (SGCN) are those that appear in the Wisconsin Wildlife Action Plan (WDNR 2005b) and include species already recognized as endangered, threatened, or special concern on state or federal lists along with more common species that are declining. There are 4 mammals, 57 birds, 7 herptiles, and 7 fish listed at SGCN for the Central Lake Michigan Coastal Ecological Landscape (see Appendix 8.E for a complete list of Species of Greatest Conservation Need in this ecological landscape and the habitats with which they are associated).

Categories of Significant Wildlife

- **Rare species** are those that appear on the Wisconsin Natural Heritage Working List as Wisconsin or U.S. Endangered, Threatened, or Special Concern.
- **Species of Greatest Conservation Need** are described and listed in the Wisconsin Wildlife Action Plan (WDNR 2005b) as those native wildlife species that have low or declining populations, are "indicative of the diversity and health of wildlife" of the state, and need proactive attention in order to avoid additional formal protection.
- **Responsibility species** are both common and rare species whose populations are dependent on Wisconsin for their continued existence (e.g., a relatively high percentage of the global population occurs in Wisconsin). For such a species to be included in a particular ecological landscape, a relatively high percentage of the state population needs to occur there, or good opportunities for effective population protection and habitat management for that species occur in the ecological landscape. Also included here are species for which an ecological landscape holds the state's largest populations, which may be critical for that species' continued existence in Wisconsin even though Wisconsin may not be important for its global survival.
- **Socially important species** are those that provide important recreational, social, or economic benefits to the state for activities such as fishing, hunting, trapping, and wildlife watching.

■ **Responsibility Species**. The lower Wolf River and its major tributaries provide highly significant spawning habitat for the lake sturgeon. This population is the largest self-sustaining lake sturgeon population in North America. Traditional spawning areas are natural in-stream riffles and rocky areas along the banks. Natural changes in the river's path along with increased shoreline development caused more and more sediment to be transported downstream, covering some of the spawning areas with silt. The addition of rock rip-rap to protect shorelines from erosion has had the unanticipated benefit of providing additional spawning areas for these prehistoric fish (WDNR 2001c). While rip-rap may help lake sturgeon, there is concern that excessive riprapping may interfere with the natural dynamics of the river such as channel meandering, and degrade habitats for other fish and for mussels, some of which also merit conservation attention.

Three fishes, the western sand darter, greater redhorse, and shoal chub, and three mussels, elktoe (*Alasmidonta marginata*), round pigtoe (*Pleurobema sintoxia*), and snuffbox, are found in large warmwater rivers such as the lower Wolf (Epstein et al. 2002a). Rare invertebrates, including Hine's Emerald dragonfly, listed as a U.S. and Wisconsin Endangered species, the Wisconsin Threatened pygmy snaketail, and rare predacious diving beetles (*Agabetes acuductus, Lioporeus triangularis,* and *Matus bicarinatus*) are found here (WDNR 2001c).

The U.S. Endangered Piping Plover (*Charadrius melodus*) once nested on the sandy beaches at Point Beach State Forest, although it no longer does so. Heavy use of beach and dune habitats by swimmers, sunbathers, and hikers precludes use of this as a nesting site for the Piping Plover.

The lower Green Bay shoreline and its islands (e.g., Cat, Kidney, and Lone Tree) were once important nesting sites for Common Tern, Forster's Tern, Caspian Tern, and Snowy Egret. Fish-eating colonial waterbirds have been affected by industrial contaminants (Steele 2007).

Rare nesting species such as the Red-shouldered Hawk, Cerulean Warbler, and Prothonotary Warbler (*Protonotaria citrea*) occur in floodplain forest habitats along the lower Wolf River. The Yellow Rail has been found in extensive sedge meadows and marshes in parts of the Central Lake Michigan Coastal Ecological Landscape.

The Upland Sandpiper (*Bartramia longicauda*) was formerly a fairly common migrant and breeder in eastern Wisconsin (Cutright et al. 2006). It needed large open grasslands, and the Central Lake Michigan Coastal Ecological Landscape where it was found in greatest abundance. It has declined since the 1990s due to expanding urbanization and residential development in open habitats near Lake Michigan along with changes in agricultural practices (A. Paulios, Wisconsin DNR, personal communication).

The Niagara Escarpment is a prominent geological feature here and supports globally rare land snails, including the Wisconsin Endangered midwest Pleistocene vertigo, the Wisconsin Threatened cherrystone drop, the Wisconsin Special Concern dentate supercoil (*Paravitrea multidentata*), the black striate (*Striatura ferrea*), and the Iowa Pleistocene vertigo (*Vertigo iowaensis*). The special habitats associated with the escarpment also support other rare species, including bats.

The highly specialized fauna associated with the Niagara Escarpment includes globally rare land snails, such as the Wisconsin Endangered midwest Pleistocene vertigo. Chicago Field Museum specimen. (Units on scale are millimeters.) Photo by Terrell Hyde and W.A. Smith, Wisconsin DNR.

Socially Important Fauna. The waters of Lake Michigan support cool and coldwater communities of native and stocked fishes in the main basin, numerous bays and harbors, and tributary streams. These fish populations support a number of commercial enterprises. Port Washington and Sheboygan had 85 licensed charter captains in 2008 (43 in Port Washington and 42 in Sheboygan), mostly taking clients to the deeper offshore waters of Lake Michigan to fish for stocked lake trout and nonnative salmon. Other charter boats operate out of Manitowoc, Two Rivers, Kewaunee, and Algoma. Shore fishing from piers and breakwalls at the ports of Algoma, Kewaunee, Two Rivers, and Manitowoc used to be a major part of the trout and salmon fishery along Lake Michigan. Although that fishery has declined during the past decade, there are popular sport fisheries for yellow perch, northern pike, walleye, and smallmouth bass in the rivers, harbors, and nearshore waters of Lake Michigan. Many streams tributary to Lake Michigan (Kewaunee, Manitowoc, Sheboygan, West Twin, East Twin, and Mullet rivers, the lower portion of the Milwaukee River in

Significant Wildlife in the Central Lake Michigan Coastal Ecological Landscape

- The Lake Michigan shoreline is an important migratory corridor for many birds, including waterfowl, loons, grebes, shorebirds, gulls, terns, raptors, and passerines.
- The Lake Michigan shoreline is an important wintering area for waterfowl and other waterbirds.
- The Lower Green Bay shoreline and its islands provide important breeding habitat for colonial nesting birds.
- The Niagara Escarpment is a prominent geological feature of the Central Lake Michigan Coastal that supports large numbers of bats, rare plant habitats, and globally rare land snails.
- Large stands of nonriparian forested wetlands of northern white-cedar, ash and tamarack are important to many bird and herptile species.
- The broad floodplain of the Lower Wolf River contains extensive marsh, wet meadow, shrub swamp, and floodplain forest habitats and is important to many birds, herptiles, and mammals.
- The Lower Wolf River and its major tributaries provide highly significant spawning habitat for the Lake Sturgeon. In general, fish diversity of the Wolf River system is high.

Ozaukee and Milwaukee counties, and many smaller tributaries) have spring and fall runs of stocked nonnative trout and salmon. It is common to see heavy fishing pressure during fall and spring along these tributary streams for coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tschawytscha*) salmon, brown trout (*Salmo trutta*), and rainbow trout (steelhead) (*Oncorhynchus mykiss*) (WDNR 2001b). The lake-wide decline of smelt (family Osmeridae) populations has led to reduced sport and commercial harvests of smelt.

Lower Green Bay and the lower Fox River support major sport fisheries. The east shore of Green Bay is important for smallmouth bass fishing, and all of Green Bay is important for walleye, yellow perch, and muskellunge (*Esox masquinongy*). Walleye and muskellunge fishing are also popular in the lower Fox up to the De Pere Dam.

Fishing is a major recreational use of the lower Wolf River, and the lower Wolf is the sixth most popular waterway in state for recreational boating. The river is popular due to its walleye, sucker (family Catostomidae), and white bass (*Morone chrysops*) runs.

Double-crested Cormorant (*Phalacrocorax auritus*) populations are viewed by some commercial and recreational anglers as nuisance predators on fish populations in Green Bay. A study of Double-crested Cormorant food habits in lower Green Bay during 2004 to 2006 found that Double-crested Cormorants primarily consumed small yellow perch and gizzard shad (*Dorosoma cepedianum*) and other species to a lesser degree (Meadows 2006). However, the degree that Double-crested Cormorant mortality is additive to yellow perch populations is still unclear. Additional study is needed to understand the population dynamics of both Double-crested Cormorant and yellow perch to clarify Double-crested Cormorant impacts on this fishery.

The Lake Michigan shoreline is an important migratory corridor used by many birds, including raptors, waterfowl, loons, grebes, shorebirds, and passerines. Feucht (2003) found migratory land birds were more abundant within 1 kilometer of the Lake Michigan shoreline in Door County and on the west shore of Green Bay than farther inland. Thousands of raptors, including all three species of Accipiters, all of the midwestern Buteos, Bald Eagle, Osprey (*Pandion haliaetus*), Northern Harrier (*Circus cyaneus*), and all the falcons may be seen along the Lake Michigan shoreline from August through November (Steele 2007). Concordia College campus along the Lake Michigan lakeshore is known as one of the premier hawk-watching areas in the Midwest. Passerines use the Lake Michigan shoreline as a landmark and a resting and foraging place. Remnant woodlots along and near the Lake Michigan shore are especially important feeding areas. Lower Green Bay, including areas such as Bay Beach Wildlife Sanctuary, is also known to be important to migrating birds.

Cedar Grove Hawk Research Station (near the Lake Michigan shore in Sheboygan County) has been active for over 60 years—the longest operating banding station in North America. Over 20,000 raptors of 23 species have been banded there (Mueller and Berger 2010). Significant migratory bird banding also occurs at Little Suamico just north of Green Bay at Woodland Dunes Nature Center in Manitowoc County and at the Urban Ecology Center at the southern tip of the ecological landscape in Milwaukee County.

Biologists at the Cedar Grove Hawk Research Station about to release four live-trapped and banded Peregrine Falcons. This banding facility has been active since the 1940s, the longest period of sustained activity for such an operation in North America. To date, over 38,000 raptors have been live-trapped, banded, and released here. Photo by Sumner Matteson, Wisconsin DNR.

■ **Wildlife Habitats and Communities.** Historically, the prevalent vegetation of this ecological landscape was mesic hardwood forest. Today only 14% of the ecological landscape is forested. It is primarily an agricultural and urban landscape with scattered, often isolated, woodlots and wetlands. However, this ecological landscape still provides important habitat for waterbirds, forested wetland birds, grassland birds, and migratory and wintering species of many taxa. The Lake Michigan shoreline is an important migratory and wintering area for many waterfowl and waterbirds. The marshes and islands in lower Green Bay are important to fish-eating birds, and the marshes and other wetlands along the lower Wolf River are important to many additional species. Floodplain forests along the Wolf and Embarrass rivers and scattered northern white-cedar, tamarack, and black ash swamps provide habitat for forest wetland species. Surrogate grasslands and the now open nature of much of the ecological landscape provides habitat for some grassland birds (e.g., Bobolink [*Dolichonyx oryzivorus*] and Upland Sandpiper). Seven Important Bird Areas have been identified and designated within or partially within the Central Lake Michigan Coastal Ecological Landscape (Steele 2007; see the "Ecologically Significant Places within the Central Lake Michigan Coastal Ecological Landscape" map in Appendix 8.K at the end of this chapter).

The Lake Michigan shoreline environments are important for breeding birds. Broetzman and Howe (2004) demonstrated that the narrow strip of land within 5 kilometers of the Lake

Michigan shoreline had higher breeding bird diversity and abundance than farther inland in eastern Wisconsin. Both the number of species and the number of birds were higher in lakeshore sites. Mourning Warbler (*Geothlypis philadelphia*), Least Flycatcher (*Empidonax minimus*), and Alder Flycatcher (*Empidonax alnorum*) were more frequent in lakeshore sites while Rose-breasted Grosbeak (*Pheucticus ludovicianus*) and White-breasted Nuthatch *(Sitta carolinensis)* were more abundant in inland sites. Although woodlots are mostly small and isolated, conservation of forest tracts near the Lake Michigan shoreline is particularly important to maintain a high diversity and abundance of breeding birds in eastern Wisconsin.

The Lake Michigan shoreline and nearshore waters are also important wintering areas for waterfowl and other waterbirds, including species of very limited distribution within the state. The harbors and offshore areas of Port Washington, Sheboygan, Manitowoc, Two Rivers, Kewaunee, and Algoma often have large concentrations of waterfowl. Long-tailed Duck (*Clangula hyemalis*), Red-breasted Merganser (*Mergus serrator*), Common Goldeneye (*Bucephala clangula*), Bufflehead (*Bucephala albeola*), Greater Scaup (*Aythya marila*), Common Merganser (*Mergus merganser*), and Black (*Melanitta americana*), Surf (*Melanitta perspicillata*), and White-winged (*Melanitta fusca*) Scoters use the waters along the Lake Michigan shoreline as fall, winter, and spring habitat. Mallard (*Anas platyrhynchos*), Black Duck (*Anas rubripes*), and Canada Goose (*Branta canadensis*) are often found along the shoreline in winter. Tens of thousands of diving ducks migrate and winter here (Mueller et al. 2010). The Horned Grebe (*Podiceps auritus*), Red-throated Loon (*Gavia stellata*), Common Loon (*Gavia immer*), and occasionally Harlequin Duck (*Histrionicus histrionicus*) and King Eider (*Somateria spectabilis*) are found along the shoreline (Steele 2007). Many of Wisconsin's rare wintering gulls such as Glaucous (*Larus hyperboreus*), Iceland (*Larus glaucoides*), Thayer's (*Larus thayeri*), Lesser Black-backed (*Larus fuscus*), Greater Black-backed (*Larus marinus*), and Ivory (*Pagophila eburnea*) Gulls may be found along the shoreline. Important Bird Areas along the Lake Michigan coast are Ozaukee Bight Lakeshore, Harrington Beach Lakeshore, Cleveland Lakeshore, and Point Beach State Forest.

The lower Green Bay shoreline and its islands (Cat, Kidney, and Lone Tree Islands) provide important nesting habitat for fish-eating colonial nesting birds such as Double-crested Cormorant, American White Pelican (*Pelecanus erythrorhynchos*), Great Egret, and Black-crowned Night-Heron (*Nycticorax nycticorax*). In the past, Common Tern, Forster's Tern, and Snowy Egret also nested here. This area is also important to nesting Herring (*Larus argentatus*) and Ring-billed (*Larus delawarensis*) gulls (Steele 2007).

Forested wetlands (mostly of northern white-cedar, ash, and tamarack) scattered throughout the interior of this ecological landscape are important to breeding species such as the Winter Wren (*Troglodytes hiemalis*), Nashville Warbler (*Oreothlypis ruficapilla*), White-throated Sparrow (*Zonotrichia albicollis*), Red-breasted Nuthatch (*Sitta canadensis*), Golden-crowned Kinglet (*Regulus satrapa*), and Northern Waterthrush (*Parkesia noveboracensis*). Although scarce in this ecological landscape, where there are bogs the habitat becomes important for mink frogs (*Lithobates septentrionalis*).

The American White Pelican (Wisconsin Special Concern) has been increasing in recent years and has established several breeding colonies in Wisconsin, including lower Green Bay. Photo by Tom Schultz.

The corridor of the lower Wolf River contains extensive bottomland hardwood forests, and Red-shouldered Hawk, Cerulean Warbler, Blue-gray Gnatcatcher (*Polioptila caerulea*), Black Duck, Black-billed Cuckoo (*Coccyzus erythropthalmus*), Yellow-billed Cuckoo (*Coccyzus americanus*), Least Flycatcher, Prothonotary Warbler, eastern red bat (*Lasiurus borealis*), and many other vertebrate species nest there. The lower Wolf system also has extensive sedge meadows and open marshes that support species such as Yellow Rail, American Bittern (*Botaurus lentiginosus*), Northern Harrier, Sandhill Crane (*Grus canadensis*), Sedge Wren (*Cistothorus platensis*), and many other open wetland species.

Almost 70% of the land area of this ecological landscape is now in agriculture (less than 5% is grassland), but it was formerly important to some declining grassland bird species. The open areas, with scattered grassy uplands, sedge meadows, and marshes within a ***matrix*** of agricultural fields still provides habitat for some grassland species such as Bobolink and Upland Sandpiper.

Historically, Lake Michigan supported six species of deep water ciscoes or "chubs": the bloater (*Coregonus hoyi*), lake herring (*C. artedii*), deepwater cisco (*C. johannae*), kiyi (*C. kiyi*), shortnose cisco (*C. reighardi*), and shortjaw cisco (*C. zenithicus*). Currently, only the bloater persists; the other five have been functionally extirpated from Lake Michigan (the deepwater and shortnose cisco are globally extinct, but the kiyi, lake herring, and shortjaw cisco persist in Lake Superior). The taxonomic validity of several of the species is questionable, but regardless of their taxonomic status, they represent unique evolutionary lineages worthy of preservation. Unfortunately, given the highly modified habitat and biological community in much of Lake Michigan, it's unlikely that any of the surviving cisco species could be restored here without major environmental improvements in the lake.

A thriving and economically important lake trout population was extirpated by the early 1950s, and although the cause is uncertain, some factors for the decline may include overfishing, habitat degradation, alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) invasions, and heavy mortality from parasitic, invasive sea lamprey. These nonnative species entered the Great Lakes via shipping canals constructed farther to the east.

Although tremendous numbers of lake trout have been stocked in the lake, and sea lamprey control efforts have kept this parasite largely in check, self-sustaining lake trout populations have not been reestablished. A lake trout restoration plan for Lake Michigan is described in an Implementation Strategy recently adopted by the Lake Michigan Committee (Dexter et al. 2011) with additional background information available in a more detailed *Guide for the Rehabilitation of Lake Trout in Lake Michigan* (Bronte et al. 2008). The current strategy relies on stocking lean lake trout in the northern refuge, mid-lake refuge, and Julian's reef (Dexter et al. 2011). Lake-wide implementation may be pursued in the future depending on the results of current restoration efforts.

Stocking programs of nonnative trout and salmon in Lake Michigan have established a sport fishery in these waters and helped to control the exotic alewife. After the devastating effects of the chinook salmon die-off during the late 1980s and early 1990s, the exotic salmonid sport fishery on Lake Michigan has rebounded in recent years. The chinook salmon die-off may have been triggered by stocking too many predatory fish for too small a prey base (WDNR 2000). It is symptomatic of what can happen in the complex and highly disturbed Lake Michigan ecosystem today. A better understanding of how this ecosystem works is critical if future management efforts are to be successful.

The waters of Lake Michigan and Green Bay are also important for yellow perch, walleye, northern pike, smallmouth bass, muskellunge, and introduced nonnative rainbow trout. Yellow perch populations have recently declined, but the direct cause for this drop in numbers is unclear.

Many rivers and streams flowing into Lake Michigan, large and small, are used seasonally by native warmwater fish and by introduced populations of salmonids that may spawn, but generally do not reproduce, on runs upstream from Lake Michigan. These Lake Michigan tributary streams include the Kewaunee, Manitowoc, Sheboygan, West Twin, East Twin, and Mullet rivers and the lower portion of the Milwaukee River in Ozaukee and Milwaukee counties, plus many smaller tributaries.

Warmwater streams such as the Wolf River support a diverse fish assemblage of 76 species (69 documented in the Wolf River in 2002), including rare and sensitive species such as shoal (speckled) chub, western sand darter, pugnose minnow (*Opsopoeodus emiliae*), river redhorse, and the globally rare lake sturgeon (Epstein et al. 2002a). Many Species of Greatest Conservation Need have been documented in the lower Wolf River, among them greater redhorse, lake sturgeon, river redhorse, western sand darter, four-toed salamander (*Hemidactylium scutatum*), wood turtle, Blue-winged Teal (*Anas discors*), and Great Egret. In addition, rare mussels such as the elktoe, round pigtoe, and snuffbox, and other rare invertebrates such as the pygmy snaketail dragonfly and several rare predacious diving beetles, are found here (WDNR 2001c).

Walleye, lake sturgeon, northern pike, and white bass migrate from Lake Winnebago upstream into the lower Wolf River, some traveling as far as 90 miles (WDNR 2001c). Walleye migrate to historical spawning marshes associated with the lower Wolf where they lay their eggs and then return to the Winnebago Pool lakes downstream. These spawning marshes have distinctive characteristics that are unique to the Winnebago Pool lakes. Well-defined inlets and outlets provide oxygenated water flows while grasses and sedges provide a silt-free spawning substrate essential for successful egg incubation and hatching. The water flow carries newly hatched fry to the river before the marshes begin to dry up in summer.

The South Branch of the Embarrass River, downstream from its last dam, supports a significant population of the snuffbox and other rare mussels. This stream also supports a population of lake sturgeon that spawns in the Embarrass River below the Pella Dam. Other coolwater streams support a fish community that transitions from cool and coldwater assemblages to warmwater species.

The Little Wolf River supports populations of the pygmy snaketail dragonfly, which was listed as Threatened in Wisconsin in 2009 (WDNR 2009). The Shioc River is important during spring when walleye and bass from the Wolf River system use the Shioc for spawning.

Natural and Human Disturbances

Fire, Wind, and Flooding

Fire-dependent vegetation is generally uncommon in the Central Lake Michigan Coastal Ecological Landscape. Due to the characteristics of the historical and present vegetation and the moist, relatively heavy soils, fire was generally a minor historical disturbance within this ecological landscape.

However, the catastrophic ***Peshtigo fire*** in northeastern Wisconsin burned an area approximately twice the size of Rhode Island, about 1.2 million acres of land. The fire began in the Northern Lake Michigan Coastal Ecological Landscape and burned the southern part of the Door Peninsula, which is in the Central Lake Michigan Coastal Ecological Landscape (Figure 8.10). Many months of extreme drought combined with the widespread land-clearing ("slash and burn") and logging practices of the time, along with sheer carelessness, caused many small fires to be whipped into a huge forest fire when a cold front with strong winds passed through the area. The fire was so intense it vaporized the soil in places (Gess and Lutz 2002), undoubtedly affecting the vegetation that was

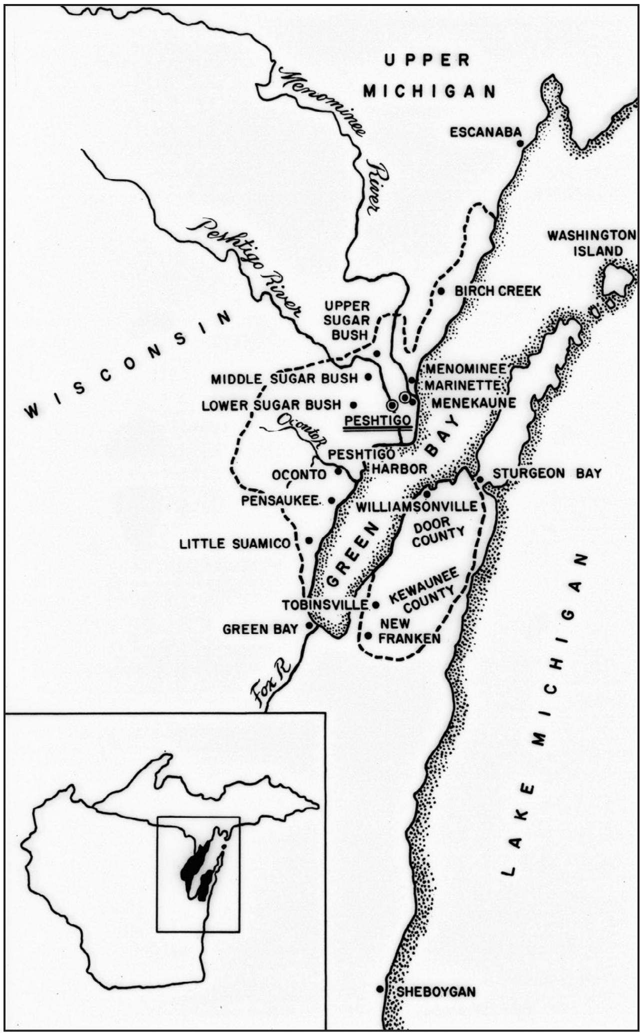


Figure 8.10. *Area burned in the 1871 Peshtigo fire. The outlined areas on the map show the extent of the most severely burned locations along Green Bay (1,280,000 acres). Map courtesy of the Wisconsin Historical Society, Image ID WHi-6783.*

able to grow after the fire. See the "Natural and Human Disturbances" section in Chapter 15, "Northern Lake Michigan Coastal Ecological Landscape," for more details about this historic fire.

Historically, windthrow was a natural disturbance that occurred characteristically and frequently in this ecological landscape. Storm events most often resulted in many small wind-fall patches (Frelich and Lorimer 1991), but some large-scale catastrophic windthrow events occurred. Wind disturbance to natural vegetation is likely reduced from historical conditions because there is much less forest now, and most of it is relatively young, although much of the remaining forest is much more exposed now, being bordered by open agricultural lands, than it would have been historically.

The extent and frequency of flood disturbance prior to Euro-American settlement is unknown. Changes in Lake Michigan water levels can have a significant effect on the extent and composition of coastal wetlands (Bosley 1978), other vegetation, and navigation. Short duration water level changes due to strong winds, barometric pressure changes, and other factors such as seiches, are usually short in duration (lasting from a few hours to a few days). Seiches can have an impact on coastal wetland vegetation due to inundation and physical force. Lower Green Bay is subject to significant seiches, which are the result of the combined effects of wind, wind direction, currents, changes in barometric pressure, and geography (see "Lake Michigan" in the "Hydrology" section of this chapter for more details). Storms on Lake Michigan can generate large waves, push ice against the shoreline, and cause the erosion of beaches and unstable bluffs. Storms and seiches can be most damaging during those periods when Lake Michigan water levels are already high.

Longer-term water level changes at periods of 10–20 years have been recognized in Green Bay since the late 1800s. These are driven primarily by precipitation cycles. Prolonged droughts or extended periods of unusually high precipitation can have significant effects on coastal wetland vegetation in Green Bay. During periods of low water the coastal wetlands can increase in extent (see "Wetlands" in the "Hydrology" section for more details).

Researchers had noted dramatic vegetation changes and losses in lower Green Bay as early as the 1940s, when wastes discharged by paper mills in the Fox River were thought to be responsible (Zimmerman 1953). Later studies also implicated pollutants, including excessive sediment inputs from agricultural uses and urban development, which resulted in reduced light penetration and diminished growth and recovery by aquatic macrophytes. The increased turbidity has been caused by human factors that have created a light-limited environment in which the germination and growth of aquatic plants have been greatly reduced (Howlett 1974, Robinson 1996). Outright wetland loss due to filling was also significant at lower Green Bay sites.

Forest Insects and Diseases

Although the Central Lake Michigan Coastal Ecological Landscape was almost entirely forested historically, it is only 14% forested today. It has a number of major forest types (e.g., northern or central hardwoods, floodplain forest, conifer swamp, and hardwood swamp), each of them hosting different insects and diseases. Thus, there are a number of insect species and pathogens that can periodically affect forests in this ecological landscape.

Aspens can be impacted by forest tent caterpillar (*Malacosoma disstria*), aspen heart rot fungus (*Phellinus tremulae*), and aspen Hypoxylon canker fungus (*Hypoxylon mammatum*).White birch can be affected by bronze birch borer (*Agrilus anxius*), and drought can predispose both white birch and aspens to these diseases. Conifers, including red and eastern white pines, can be affected by Annosum root rot, caused by the fungus *Heterobasidion annosum*, particularly in plantations. Red pine (*Pinus resinosa*) is also subject to pocket mortality, which is caused by a complex of insects and the fungal species *Leptographium terrebrantis* and *L. procerum*. Red pine is also susceptible to pine blight fungus (*Diplodia pinea*) and pine sawfly (*Neodiprion* spp., *Diprion* spp.). White pine blister rust is an introduced fungal disease caused by *Cronartium ribicola*.

Dutch elm disease is caused by the fungus *Ophiostoma ulmi*, which is transmitted by two species of bark beetles or by root grafting. American elm, *Ulmus americana*, is more seriously affected than other elm species, but all of our native elm species are somewhat susceptible, as is the nonnative Siberian elm (*Ulmus pumila*). American elm has essentially been eliminated as a component of the forest overstory but can still be a significant part of the forest understory. Its life span is typically now about 30 years before it succumbs to Dutch elm disease. The loss of American elm as a dominant or ***supercanopy*** tree has had impacts on cavity-nesting and other associated wildlife species such as the Wood Duck (*Aix sponsa*). Along with the invasion of sparsely canopied lowland hardwood forests by reed canary grass, Dutch elm disease is a major problem in regenerating bottomland forests.

The emerald ash borer is an exotic insect native to Asia. In the Central Lake Michigan Coastal Ecological Landscape, this extremely serious forest pest has been confirmed in Brown, Calumet, Ozaukee, and Sheyboygan counties (Figure 8.11). Kewaunee, Manitowoc, and Outagamie counties have also been also placed under quarantine because of their proximity to affected counties in an effort to help prevent the human-aided spread of the emerald ash borer, which may be present in ash nursery stock, ash firewood and timber, or other articles that could spread emerald ash borer into other parts of Wisconsin or other states. See the Wisconsin emerald ash borer website (WDATCP 2014) for up-to-date information on its current distribution.

Attempts to contain infestations in Michigan by destroying ash trees in areas where emerald ash borer was found have not been successful, perhaps because the insect was already well established before it was found and identified. The emerald ash borer typically kills a tree within one to three years. In greenhouse tests, the emerald ash borer has also been shown to feed on some shrub species such as privets (*Ligustrum* spp.) and lilacs (*Syringa* spp.), but it is still unknown as to whether shrub availability will contribute to its spread under field conditions. Despite the reduced amount of forest now present in this ecological landscape, the emerald ash borer may become a serious threat here. Of the forests that still exist, there is a large percentage of lowland forest (37%) in which ash trees are common, and ash trees have been planted in many unban areas.

Asian longhorned beetle (*Anoplophora glabripennis)* is an insect not yet found in Wisconsin but one that would have major consequences if it were to become established. It is a major pest of all maples, and although it prefers maples, it will attack other hardwoods. Asian longhorned beetle was discovered in the Chicago area in 1998, and additional infestations have since been found elsewhere in North America

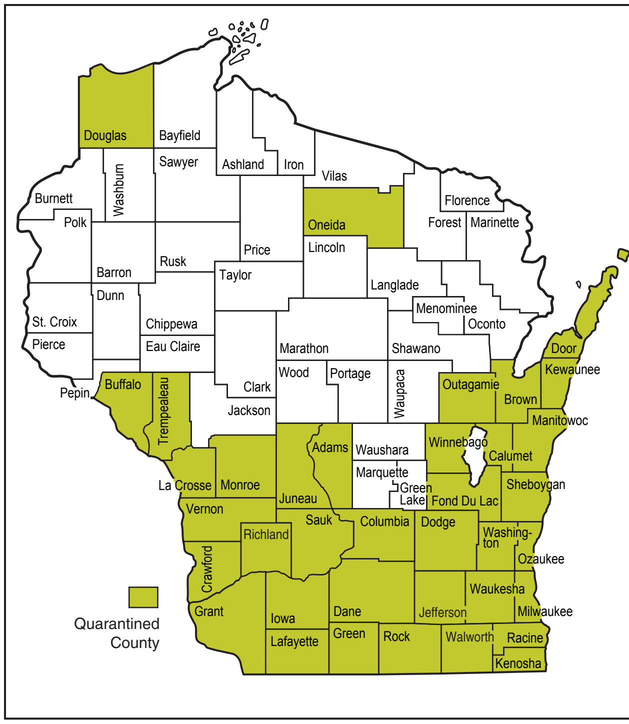


Figure 8.11. *Locations of the emerald ash borer and counties that are quarantined in Wisconsin, October 2014 (WDATCP 2014). Reprinted with permission from Wisconsin Department of Agriculture, Trade, and Consumer Protection.*

and in Europe. The insect is believed to have entered North America inside wood packing materials and was likely introduced several times. The insect has thus far been contained in the Chicago area by destroying all susceptible trees in areas where it has been found; however, because new occurrences are occasionally discovered, a monitoring and eradication program continues. Because containment has apparently been successful so far, there is hope that this insect may not become established in Wisconsin.

Gypsy moth is now established throughout the Central Lake Michigan Coastal Ecological Landscape but is not expected to have large effects here, since most forest types are mesic and lowland forests. Its populations are expected to increase occasionally in the way a native insect would become more common at times. Impacts are expected to be variable, with some defoliations limited in extent and others larger. As gypsy moth defoliates trees, it is an additional stressor that can further weaken already drought-stricken or diseased trees. It's unlikely that gypsy moth alone would kill a tree but in combination with other factors could result in mortality. New England states are seeing a 30-40 year outbreak interval, on average, though this is highly variable. Typically, drought precedes or coincides with gypsy moth outbreaks. Egg masses can be monitored to determine when a population increase large enough to produce defoliation is imminent.

Beech bark disease is a major threat to American beech in eastern North America, including this ecological landscape.

The disease is the result of an interaction between a beech scale insect (*Cryptococcus fagisuga*) and one of several species of fungi, and the disease does not occur if either is absent. One fungus (*Nectria galligena*), is native to North America, and the other fungus, *Nectria coccinea* var. *faginata*, is introduced. Beech scale insects were accidentally introduced from Europe into Nova Scotia, Canada, around 1890. By the 1930s, the scale and an associated *Nectria* fungus were found to be killing beech trees in eastern Canada and Maine. The disease has continued to spread and was discovered in Door County in September 2009. Because the disease requires both the insect and fungus, killing the scales will prevent the disease from occurring. However, at large scales this is impractical. A small percentage of trees are resistant to the scale and do not develop disease symptoms, even in heavily infested stands. Therefore, breeding resistant trees is a possible long-term management option. Management options depend on whether the infestation is small and isolated or widespread (and whether or not resistant trees are present, as stated above). Currently, there are no special recommendations for managing beech bark disease in preparation for its spread in Wisconsin. However, when a stand is marked for thinning during the next regularly scheduled entry, consideration should be given to removing American beech trees with low vigor and/or rough bark. Retain the vigorous American beech trees with smooth bark and keep the stand adequately stocked. Management guidelines may change over time due to changing disease distribution and new research findings.

More information about these forest diseases and insect pests of forest trees can be found at the Wisconsin DNR's forest health web page (WDNR 2014a) and at the U.S. Forest Service Northeastern Area forest health and economics web page (USFS 2014).

Invasive Species

Due to the long history and intense level of development in the Central Lake Michigan Coastal Ecological Landscape, there are many nonnative invasive species that are problems. This ecological landscape is relatively vulnerable to additional invasions and to the spread of already established invasive species into other areas. Human travel, by private and commercial vehicles, ships, railroads, and other means, is a major vector for transport of a variety of invasive species and, with recreation and further development, make this ecological landscape a likely region for new introductions and the further spread of invasives that are already established.

In forested community types, glossy and common buckthorn (*Rhamnus frangula* and *R. cathartica*), nonnative honeysuckles, garlic mustard, Japanese barberry (*Berberis thunbergii*), Dame's rocket (*Hesperis matronalis*), multiflora rose (*Rosa multiflora*), Norway maple (*Acer platanoides*), Autumn olive (*Eleagnus umbellata*), Russian olive (*Eleagnus angustifolia*), and black locust (*Robinia pseudoacacia*) already pose problems. These species may initially colonize disturbed areas and edges but once established can spread and continue to invade surrounding habitats. The exotic European marsh thistle (*Cirsium palustre*) has become a serious problem in calcareous wetlands, including northern white-cedar swamps and northern fens in northeastern Wisconsin.

Although native grassland communities are rare here, problem invasive species include crown vetch (*Coronilla varia*), cut-leaved teasel (*Dipsacus laciniatus*), bird's foot trefoil (*Lotus corniculata*), white and yellow sweet clovers (*Melilotus alba* and *M. officinalis*), wild parsnip (*Pastinaca sativa*), and autumn olive. Surrogate grasslands, composed of nonnative grasses and forbs that may include some of these nonnative invasive species, can provide important habitat for declining grassland fauna. The desirability and especially need for control will depend on site-specific factors as well as site context. If the site supports declining wildlife species and the invasives present are not likely to spread to and negatively impact significant native vegetation, control measures may be less critical.

The exotic lyme grass (*Leymus arenarius*) is a serious problem in Lake Michigan dune and beach habitats. This species is well established in this ecological landscape at Point

Understory of eastern white pine forest on stabilized dunes is now dominated by invasive shrubs. Sheboygan County. Photo by Eric Epstein, Wisconsin DNR.

*The exotic, highly invasive lyme grass and the native marram grass (*Ammophila breviligulata*) at Kohler-Andrae State Park, Sheboygan County. Photo by Owen Boyle, Wisconsin DNR.*

Beach State Forest in Manitowoc County. Common reed and purple loosestrife are problematic invaders of the interdunal swales at the same site.

In aquatic and wetland ecosystems, the primary problem species are mostly narrow-leaved and hybrid cat-tails, Eurasian water-milfoil, curly pondweed (*Potamogeton crispus*), common reed, purple loosestrife, reed canary grass, and rusty crayfish (*Orconectes rusticus*). Common carp, present in the area for at least 125 years, continue to cause major problems in shallow lakes here by destroying native aquatic plant beds and suspending fine sediments and associated nutrients. Common carp are also in Lake Michigan but are less of a problem there; however, they are a problem in Green Bay in localized areas of shallow bays and harbors.

In recent decades, there has been a radical, possibly irreversible, shift in the species composition of many of the marshes and sedge meadows bordering the west shore of Green Bay. This was apparently triggered by the response of invasive plants to dramatic water level changes in the bay (Meeker and Fewless 2008). In 1986 water levels reached a historic high. During the period from 1997 to 2001, water levels reached a historic low, and invasive common reed, narrow-leaved cat-tail, and common cat-tail became the overwhelmingly dominant species in the west shore marshes, especially in lower Green Bay, crowding out native plants (Frieswyk and Zedler 2007). This link provides a summary of a workshop laying out the problems and presenting some possible solutions: **http://naturalresources.uwex.edu/invasive/pdf/Huff_compressed.pdf**. A cooperative effort between the Wisconsin DNR and the U.S. Fish and Wildlife Service is underway to try to control these invasive species across 600 acres in several areas of lower Green Bay. Herbicide application has been followed with mowing and prescribed burning. This treatment resulted initially in the reestablishment of native wetland species. However, control is not 100% effective, and over time, treated areas are slowly reverting back to a common reed-dominated plant community. Other invasive species found in and along lower Green Bay are reed canary grass and Eurasian water-milfoil.

Nonnative species such as the sea lamprey, alewife, rainbow smelt, round goby (*Neogobius melanostomus*), spiny water flea (*Bythotrephes cederstroemi*), and zebra mussel are affecting ecological functions in Lake Michigan and Green Bay. More recently, the zebra mussel is being replaced throughout Lake Michigan by a closely related, ecologically similar species, the quagga mussel. The zebra mussel and the more recent quagga mussel expansion appear to be associated with a precipitous decline in populations of the small, shrimp-like amphipod *Diporeia hoy*i that historically has supported an abundance of lake whitefish, lake trout, bloater, slimy sculpin (*Cottus cognatus*), and other important species (Hondorp et al. 2005). In recent years, the zebra and quagga mussels have been implicated in massive blooms of native filamentous green algae in the genus *Cladophora*. Cladophora is a green algae found naturally along the Great Lakes coastlines. It grows on submerged rocks, logs, or other hard surfaces. Because quagga and zebra mussels are such efficient filter feeders, Lake Michigan's water clarity has increased, and Cladophora can now grow in well over 30 feet of water. Wind and wave action cause the algae to break free from the lake bottom and wash up on shore. There the algae decompose and create a stench that permeates the atmosphere for miles. Thus far, this problem has been termed as primarily a "nuisance," with no direct adverse health impacts. See Chapter 5, "Current and Emerging Resource Issues," for a detailed description of the relationship between zebra and quagga mussels and Cladophora.

The nonnative alewife and rainbow smelt historically had major effects on native fishes in the Great Lakes through predation on plankton and on fish larvae. Alewives and rainbow smelt have declined in abundance recently. Alewives, in addition to feeding on *Diporeia*, ate the larval forms of many fish species. In Lake Huron, the near disappearance of alewives is credited, in part, with the rebound of native walleyes, lake herring, lake trout, and emerald shiners (*Notropis atherinoides*) (Erikson 2009). Researchers are attempting to determine the chances that the decline in *Diporeia*, and thus alewives, might mean a return of the formerly abundant native fish species (Erikson 2009). White perch (*Morone americana*) and three-spine stickleback (*Gasterosteus aculaeatus*), which are native to the Atlantic coastal region but not in Lake Michigan, are present. Their impacts in this ecological landscape are largely unknown. The zebra mussel is rapidly invading inland lakes in southern Wisconsin, including those in this ecological landscape, where they often reach high densities and likely have a significant (but as yet undetermined) ecological impact.

Halting the introduction of additional exotic species will be essential to allowing the Great Lakes ecosystem to recover from the disruptions caused by these past introductions. This was one of the top nine priorities identified by the Council of Great Lakes Governors as of December 2005 (CGLG 2014).

Nevertheless, "recovery" in this dynamic and highly perturbed ecosystem will almost certainly bring its share of surprises.

For more information on invasive species, see the Wisconsin DNR's invasive species web page (WDNR 2014c).

Land Use Impacts

Historical Impacts. There have been dramatic changes in land use and land cover in this ecological landscape. Euro-American settlers cut the forests for lumber, then cleared uplands and drained wetlands to create farmland. The vegetative cover went from almost entirely forest at the time of Euro-American settlement (96% of the ecological landscape according to Finley [1976]), to primarily agricultural fields and pastures, with scattered ***second growth*** woodlots, riparian areas, and wetlands that were too difficult to drain. In 1992 the ecological landscape's land cover was 69% agriculture, 7% upland forest, 7% lowland forest, 7% nonforested wetlands, 5% grasslands, and 4% urban according to WISCLAND data (WDNR 1993b). By the percentage of land remaining in upland forest compared to land dedicated to agriculture, this is the least forested and second most agricultural ecological landscape in the state today. The Central Lake Michigan Coastal Ecological Landscape has the fourth greatest number of acres in agriculture (the Western Coulees and Ridges, Forest Transition, and Southeast Glacial Plains have more) and the second least number of acres in upland forest (the small and highly urbanized Southern Lake Michigan Coastal has less). The natural hydrological regimes of many rivers and streams have been altered by dam construction, channelization, loss of shoreline cover, and extensive ditching, diking, tiling, and filling of wetlands. In addition, many wetlands have been grazed, which has led to an increase in invasive plants such as reed canary grass at the expense of native wetland species. Industries have flourished in some parts of this ecological landscape, resulting in serious water pollution in areas such as the lower Fox River and lower Green Bay.

Current Impacts. Current disturbances in the ecological landscape are largely due to human activities, primarily associated with agriculture, industrial activity, and urbanization. Indirect effects of these changes in land use and cover have resulted in poorer water quality, elimination or fragmentation of habitats, and alteration of natural disturbance regimes. Flood frequency and severity have likely increased within this ecological landscape because of wetland drainage and stream channelization. Construction of dams on major rivers has blocked or otherwise disrupted the movement of fish. Dams, industrial pollution, and runoff from agricultural fields, construction sites, and impervious surfaces have degraded water quality, especially in the lower Fox River and lower Green Bay areas. Most Lake Michigan estuaries have been at least partially filled, drained, or altered and are now occupied by cities.

Changes in Hydrology. Many dams were constructed to power mills in this ecological landscape. Regardless of size, dams can have profound effects on stream ecosystems. Dams change flowing waters into bodies of water that more closely resemble lakes, rendering habitats unsuitable for many species adapted to a riverine environment. Dams prevent or slow the movement and migration of fish and other aquatic life within stream ecosystems, thereby having effects that can reverberate throughout a stream's food web. Streams rely on periodic high flows to remove sediments, especially fine sediments; dams can dampen that effect. Instead of fine sediments being suspended in the water column and deposited on the inside of river bends (meanders), they get deposited behind dams and cover the coarser debris such as gravel, cobbles, or boulders, which many species rely on for reproduction and habitat. Waters impounded behind dams often have low oxygen levels and attract tolerant ***rough fish*** such as common carp. Inundation caused by dikes and dams built to provide habitat for waterfowl species has converted some wetland communities in the ecological landscape, for example, from floodplain forest to marsh.

Riparian corridors have been modified by the removal of vegetation from streambanks and floodplains. Land was often cleared right up to the river or stream bank to obtain or move forest products and to maximize the amount of land that could be put into agricultural production. The riparian corridor adjacent to a stream is a very important part of the stream ecosystem that benefits water quality, plants, and wildlife. Prior to intensive development, most of the streams in the ecological landscape were lined with trees or various kinds of wetland vegetation (forested, shrub, or open). As lands were cleared, agricultural and urban developments replaced the natural corridors adjacent to river and streams. Water quality declined as the streams lost the benefits of shading, flood retention, and soil retention that the vegetation along streams provided. Trees, shrubs, and grasses provide shade that help keep water cool, stabilize streambanks, filter runoff, and attract insects that are used as food by other organisms. Riparian vegetation also provides movement corridors, and resting and nesting areas for wildlife. Trees that fall into the water provide cover for fish and basking substrates for snakes and turtles. Without the continuous wildlife "highways" provided by riparian vegetation, habitat becomes fragmented and isolated, and wildlife populations often decline. Floodplain corridors also absorb water during snowmelt and high rain events, reducing flooding.

Many wetlands in this ecological landscape were filled or drained for agricultural, industrial, and residential developments. The reduction and degradation of wetlands can lead to consequences such as increased flooding during spring runoff and storm events, less filtering of nutrients and contaminants from runoff water from adjacent areas, and a reduction in water quality. Modifications such as stream channel straightening (channelization) have proven to be detrimental to water quality and aquatic and riparian habitat. Small streams were channelized to facilitate drainage and allow for agricultural and urban expansion. Straightening stream channels increases stream velocity and energy, which can ultimately contribute

Embarrass River floodplain. Note the area in the upper center portion of the photo, where floodplain forest has been converted to more open wetland communities via construction of a dike system. Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

The forested floodplain of the Embarrass River is bordered by agricultural lands dedicated to intensive row crop production. Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

to increased and more severe flooding, greater erosion, and poor water quality. Wet fields were tiled to make the land more suitable for agriculture, lessening groundwater recharge.

A period of high water occurred in Green Bay in 1974, but then the water level dropped until 1980 (Fewless undated). The water level rose through the early 1980s and peaked in 1986 and was followed by precipitous water level drops in the late 1980s and through the 1990s. These lows reached historic levels around 1999–2001 when water levels in Green Bay dropped by 4 feet, the largest drop on record for the last 30 years. This created unprecedented exposures of sand and silty mud. These newly exposed substrates were rapidly colonized by the exotic and highly invasive narrow-leaved cat-tail and hybrid cat-tail and later by the nonnative strain of common reed (Frieswyk and Zedler 2007). These aggressive plants were already established at the highly disturbed mouth of the Fox River at the head of Green Bay but

Drained tamarack swamp. Photo by Eric Epstein, Wisconsin DNR.

quickly became dominant in the exposed unvegetated areas and spread explosively throughout many of the lower Green Bay marshes. This resulted in a very rapid and almost complete turnover in marsh plant composition, from a relatively diverse assemblage of mostly native species, to almost total dominance by the exotics, common reed, narrow-leaved cat-tail, and hybrid cat-tail (Frieswyk and Zedler 2007, Meeker and Fewless 2008). Botanist Gary Fewless at the University of Wisconsin-Green Bay has developed a website that clarifies and illustrates the dynamic nature of and changes to the lower Green Bay marshes (Fewless undated).

Global climate change could have a major influence on Great Lakes' water levels, coastal wetlands, beach and dune systems, and other shoreline features. The Great Lakes shorelines are dynamic and support species, vegetation, and landforms that are dependent upon variability but within certain limits. Stabilization of water levels (usually to facilitate certain types of economic activity or recreation) would almost certainly be accompanied by additional major and largely unforeseen impacts to coastal ecosystems.

Population growth and urban sprawl in the Fox River valley has long resulted in increased groundwater withdrawal and declining groundwater levels. Pumping from closely spaced wells and pumping for industrial purposes had resulted in a steady decline in groundwater levels since the 1950s (WGCC 2013). In the mid-1990s, the Wisconsin Geological and Natural History Survey estimated that at then-current pumping rates, wells located in central Brown County, including the villages of Allouez, Ashwaubenon, Bellevue, De Pere, Hobart, Howard, Lawrence, Ledgeview, Scott, Suamico, and the Oneida Tribal lands, would not be able to provide enough groundwater in 10 to 15 years without additional wells and optimized pumping schedules (Grundl and Bradbury 2000). Many of these communities combined to create the Central Brown County Water Authority and entered into an agreement with the City of Manitowoc to supply Lake Michigan water through a newly constructed pipeline (Central Brown County Water Authority 2009). The City of Green Bay is seeking approval to test on a limited basis a new method known as aquifer storage and recovery (ASR) that may help the city meet its future water needs. An ASR system enables treated drinking water from a municipal water system to be stored in a deep sandstone aquifer during periods of low demand and subsequently recovered during periods of high demand.

Declining groundwater levels impact water quality. Wells must be deepened as groundwater levels drop. The deeper aquifers expose water to surrounding rock layers for a longer time. Over time, minerals in these rock layers dissolve in groundwater, creating higher concentrations of natural contaminants such as radium, iron, or arsenic. The dropping water table also alters groundwater flow patterns and allows oxygen deeper into the deep aquifer system. This releases arsenic and metals into groundwater. Nickel, cadmium, cobalt, and zinc have all been recorded at levels well above the U.S. Environmental Protection Agency maximum contaminant level (MCL) and levels specified by State groundwater quality standards (Wis. Adm. Code, Chapter NR 140). Naturally occurring contaminants that are frequently found in groundwater in the lower Fox River valley include arsenic, radium, and nitrate. Radium concentrations in municipal wells exceed the federal drinking water MCL in the Lower Fox River basin. The lower Fox River communities of Allouez, Ashwaubenon, Bellevue, De Pere, Forest Junction, Howard, and Ledgeview have been required to install water softening units to treat groundwater high in radium, or to obtain drinking water from Lake Michigan. (The switch to Lake Michigan water has enabled the deep aquifer to recover by 100 feet to as much as 150 feet in this area, helping to reduce radium concentrations by reducing direct contact of oxygen with the radium-bearing rock layers (Maas 2010).) Bacterial contamination of groundwater is also a concern in this ecological landscape. Coliform bacteria and fecal bacteria are commonly found in private wells, particularly those short-cased wells in which the casing is not installed to a proper depth and that are located near Green Bay and in areas in the southern part of the ecological landscape (e.g., Neenah, Menasha) where the fractured dolomitic bedrock is not far below the ground surface (WDNR 2001a).

■ **Water Pollution.** The Fox River valley is the second largest urbanized area in the state of Wisconsin. Most of this urban area (which includes the cities of Kimberly, Kaukauna, Little Chute, Combined Locks, Appleton, and Green Bay) is within the Central Lake Mighigan Coastal Ecological Landscape. Most of the urban areas here are near the Fox River and lower Green Bay, into which urban and industrial runoff have contributed to water quality problems. Industries along the lower Fox River and Green Bay have deposited contaminants into the river and Green Bay, causing problems for fish, wildlife, and humans (see "Contaminants" below). Large common carp populations stir up bottom sediments when feeding, contributing to high turbidity, and suppress the growth of desirable plants and other organisms.

As agricultural practices become more intensive and rural areas become urbanized, the potential sources of pollution to surface and groundwater increase. Runoff from point and nonpoint sources, contaminated sediments and habitat modifications (such as channelization, ditching, and dam construction) have degraded water quality throughout the ecological landscape. Construction site erosion and an increase in impervious surfaces (roads, roofs, parking lots) are serious threats to water quality in the more urban parts of the ecological landscape. Diminished water quality and degraded habitat can be detrimental to sensitive aquatic species. See the "Water Quality" section in "Hydrology" for more details.

■ **Contaminants.** The accumulation of ***polychlorinated biphenyls*** (PCBs) and other toxins in the sediments of lower Green Bay and the lower Fox River as a by-product from paper industry wastes has been significant in this ecological landscape. This has reverberated through parts of the food web, causing physical anomalies and reproductive problems for some fish-eating birds. Gulls, terns, herons, Bald Eagles, and Double-crested Cormorants have all been known to be affected by high contaminant loads from these chemicals. Health advisories that suggest limits to the amount and type of fish that humans can safely consume have been in place for several decades in this area. Lake Michigan, Green Bay, and their tributaries streams, as well as the Sheboygan River and the Manitowoc River above Clarks Mills Dam, have fish advisories for PCBs. Given the importance of sport fishing in the Central Lake Michigan Coastal Ecological Landscape, contaminants will continue to be a significant ecological and socioeconomic issue well into the future.

PCBs are colorless, odorless chemical compounds with low electrical conductivity that were widely used in electrical equipment and a variety of commercial applications, including adhesives, paints, and carbonless copy paper, for five decades. The Fox River valley in northeastern Wisconsin is home to the largest paper production industry in the world. Before they were banned in 1979, PCBs were used by paper mills in this ecological landscape and elsewhere as a vehicle for holding and delivering ink in carbonless copy paper. Over 95% of the PCBs in Green Bay are derived from the lower Fox River. It has been estimated that approximately 160,000 pounds of PCBs have already escaped the lower Fox River into Green Bay and Lake Michigan. In addition, up to 612 pounds of PCBs are estimated to be bound to sediments and transported from the Fox River into Green Bay annually, based on data collected in 1989–90 (WDNR and USEPA 2001). More than 2,200 pounds of PCBs were transferred from the Fox River to Green Bay during the 1990s. As a result, PCB concentrations in the bay's surface sediments, where they are most bioavailable, did not improve and remained unacceptably high. In addition to the river sediments, PCBs have also been detected in many fish and bird species in the lower Fox River and in Green Bay. PCBs concentrate in the fatty tissues of fish that ingest contaminated river sediment with their food, and they get passed up the food chain in a process called bioaccumulation.

A program to dredge a large volume of PCB-contaminated sediment from Green Bay began in 2009 and is scheduled for completion in 2015. Removal of contaminated sediments from the lower Fox River will help stop more PCBs from entering Green Bay, where they are much more difficult and expensive to capture and clean up. Removal of PCB-contaminated sediments from the Fox River bed using environmental dredging (see below) in all areas that have PCB contamination greater than one part per million is underway. Environmental dredging using a GPS-guided vacuum-like process is employed to remove sediment from the river bottom without stirring it up, so the contaminants are not distributed and the water remains fairly clear. Dewatering (drying out) the dredged sediments and disposing of them at appropriately designed and licensed landfills is the next step. The selected remedy for lower Green Bay is monitored natural recovery. Monitored natural recovery involves allowing natural processes to break down, bury and dilute the PCBs until they are no longer a threat to the environment or human health. This method includes a long-term monitoring program for measuring PCB levels in the bay so that progress toward cleanup goals can be assessed.

Great Lakes Areas of Concern (AOCs) are severely degraded geographic areas within the Great Lakes basin. They are defined by the U.S.-Canada Great Lakes Water Quality Agreement (Annex 2 of the 1987 Protocol) as "geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life" (GLIN 2008). The U.S. and Canadian governments have identified 43 such areas: 26 in U.S. waters, 17 in Canadian water, and 5 shared between the U.S. and Canada on connecting river systems. The Great Lakes Water Quality Agreement, as amended via the 1987 protocol, directs the two federal governments to cooperate with state and provincial governments to develop and implement Remedial Action Plans for each AOC. Two Great Lakes Areas of Concern are located in the Central Lake Michigan Coastal Ecological Landscape—the lower Green Bay and Fox River AOC and the Sheboygan River AOC.

Figure 8.12. *Location of the Green Bay/Fox River Area of Concern.*

Lower Green Bay/Fox River Area of Concern. This AOC consists of the lower 11.2 kilometers of the Fox River below the DePere Dam and a 55-square-kilometer area of southern Green Bay out as far as Point au Sable and Long Tail Point (Figure 8.12.). The drainage area encompasses portions of 18 counties in Wisconsin and 40 watersheds of the upper Fox River, Wolf River, and the Fox River basins, including the largest inland lake in Wisconsin, Lake Winnebago, and its connected "pool" lakes. While water quality problems and public use restrictions are most severe in the AOC, water resources of the entire basin are affected by runoff pollution from urban and rural areas, municipal and industrial wastewater discharges, airborne pollutants such as mercury, and degraded habitats.

Eleven use impairments have been documented, and two are suspected of being impaired for the lower Green Bay and Fox River AOC (USEPA 2013a). Soil erosion and runoff pollution cause most use impairments from upstream tributaries, while ***persistent bioaccumulative contaminants*** and habitat losses are impairments in the lower Fox River and lower Green Bay sediments. Turbid, algae-laden waters degrade aquatic habitats and restrict use of the waters for swimming. Consumption advisories warn against eating mallard ducks and 12 species of fish. Shipping and navigation are impaired by sediment loading and accumulation from soil erosion and there is a high cost associated with dredging and disposing of contaminated sediments. Reversing the hypereutrophic conditions in the Fox River and lower Green Bay is a top priority for the AOC.

A ***Remedial Action Plan*** for the lower Green Bay and Fox River AOC linked many water quality impairments to the presence of PCBs in the lower Fox River and Green Bay sediments and identified goals, objectives, and a framework for conducting remedial actions (WDNR 1993a). A series of studies in the mid-1970s concluded that PCBs in the lower Fox River and Green Bay presented an unacceptable level of risk to human health and the ecosystem (WDNR and USEPA 2001). The conclusion that PCBs are unacceptably high is also reflected in the fish consumption advisories that have been in place for this region continuously since the risks were first evaluated in 1976. Other industrial contaminants remaining in sediments include dioxins and furans; the pesticide DDT and its metabolites (DDD and DDE), the pesticide dieldrin, and arsenic, lead, and mercury. The impacts of the excess nutrients in these wastes have been greatly reduced since implementation of the Clean Water Act in 1972.

Sheboygan River Area of Concern. The lower 22.5 kilometers of the Sheboygan River and harbor were designated a Great Lakes ***Area of Concern*** in 1987 because of water quality and habitat problems associated with the historical discharge of pollutants into the river and the potential adverse effect the pollutants could have on Lake Michigan (USEPA 2013b). High levels of nutrients, solids, and toxins entering the river had caused a series of problems, including nuisance algal blooms, fish consumption advisories, and contaminated sediments. The pollutant discharges were suspected of contributing to the degradation of wildlife, fish, benthos and plankton populations, and the reduction in fish and wildlife habitat in the Sheboygan River and harbor. Fish and waterfowl consumption advisories are in effect for the Sheboygan River because of elevated PCB concentrations. Anglers are advised not to eat any resident fish (e.g., smallmouth bass, walleye, common carp, or panfish) caught in the Sheboygan River and to consult the fish advisory about consumption of migrating trout and salmon.

Sediments were contaminated with high concentrations of PCBs, ***polycyclic aromatic hydrocarbons (PAHs)***, and heavy metals (USEPA 2013b). Some deposits were considered heavily polluted according to U.S. Environmental Protection Agency guidelines and Wisconsin DNR draft sediment criteria. Fish health assessments were conducted by the Wisconsin DNR on white suckers (*Catostomus commersonii*) in the river in 1994. The research concluded that white suckers residing in the lower Sheboygan River were exposed to and absorbed significant amounts of PCBs and PAHs and exhibited biochemical, histological, and hematological alterations, suggesting impaired fish condition. Reproductive problems were suspected in American mink (*Neovison vison*) because of their low population levels in relationship to available "high quality" habitat. A study that examined four species of birds collected along the Sheboygan River concluded that reproductive impairments were suspected because of the PCB tissue concentrations found.

The Wisconsin DNR and Sheboygan River Basin Partnership worked together to implement a Remediation Action Plan (RAP). In 1994 a revised RAP was prepared by WDNR and other stakeholders that outlined activities to implement a strategy for restoring water quality, fisheries, recreational uses, and other benefits of the Sheboygan River basin. The RAP goals and objectives are to "(1) protect the ecosystem, including humans, wildlife, fish and other organisms, from the adverse effects of toxic substances; (2) maintain and enhance a diverse community of terrestrial and aquatic life and their necessary habitat; (3) control eutrophication and sediment loadings to the Sheboygan River for the protection of Lake Michigan; and (4) restore the river so that it is of recreational quality from its source to Lake Michigan" (WDNR 1995). In 2013 dredging and habitat restoration projects were completed for the Sheboygan River AOC, using Great Lakes Restoration Iniative Funding (USEPA 2013b).

Urbanization. Urbanization has been an extensive disturbance in this ecological landscape. Urbanization has occurred and is increasing, especially near the larger cities (e.g., Green Bay, Appleton, Manitowoc-Two Rivers area, Sheboygan, and north of Milwaukee). Urbanization is a permanent change to the landscape and has created large areas of impervious surfaces from which polluted runoff has degraded water quality. Urbanization has destroyed some habitats (wetlands and forests) and resulted in habitat fragmentation and loss of connectivity of habitats in less urbanized areas.

Agriculture. Prior to Euro-American settlement, the Central Lake Michigan Coastal Ecological Landscape was vegetated with hardwood forests and various types of wetlands. Most of the forest was quickly cleared by newly arrived settlers for agricultural purposes. WISCLAND land use/land cover data from 1992 indicates that farming occurred on over 69% of this ecological landscape at that time (WDNR 1993b). Today agriculture generally implements conservation practices that minimize or reduce soil erosion and loss, but there are still concerns about nonpoint pollution from farms. In addition, groundwater contamination via agricultural use has been and may remain an issue in some parts of this ecological landscape where fractured bedrock is close to the surface (e.g., the Niagara Escarpment).

The trend in the dairy industry for consolidating small family farms into larger operations has greatly increased the concern for management of manure in this ecological landscape. A common practice for many large farms, both dairy and hog, is to have storage facilities that hold manure, which is then spread on adjacent fields. Liquid or solid manure spread on steep slopes, near waterways, or on frozen soil or not plowed under soon after spreading can cause oxygen depletion and phosphorus loading in nearby waters after heavy rains. This can result in fish kills or contribute to excessive algae or other aquatic plant production in nearby lakes and streams. Improperly managed manure storage facilities can cause the same problems. Fischer Creek, once a good quality coldwater stream in Manitowoc County, had major fish kills in 1998 and 2004 linked to manure runoff. Nine miles of the Branch River suffered a similar fate in fall 2000 (WDNR 2001b).

■ **Energy Development.** This ecological landscape has the highest wind resources in the state (see "Renewable Energy" in the "Socioeconomic Characteristics" section of this chapter). Industrial wind development is occurring here at seven locations, with six more sites being proposed along the Niagara Escarpment (see "Wind" in the "Socioeconomic Characteristics" section). There is concern that bird, and especially bat, mortality at these wind power sites could occur or increase. However, recent research has suggested that if wind facilities are sited away from migratory pathways and concentration areas of birds and bats (e.g., stopover areas, hibernacula), mortality may be reduced. There is a major concern regarding the siting of industrial wind facilities in or near Lake Michigan because the shoreline and nearshore waters are major migratory pathways and wintering areas for birds.

Two nuclear power plants are located on the shores of Lake Michigan (Point Beach and Kewaunee) within this ecological landscape. Nuclear power plants may cause impacts from nuclear waste storage and disposal, security, transportation of wastes, and cleaning up decommissioned plants.

Outstanding Ecological Opportunities in the Central Lake Michigan Coastal Ecological Landscape

- Lake Michigan shoreline features: complex ridge-and-swale landforms, estuaries, beaches, dunes, conifer-hardwood forests, endemic and other rare species.
- Lower Green Bay: extensive marshes and other wetlands.
- Lower Wolf River corridor: extensive floodplain, with a diverse mosaic of wetland communities. Many rare and/or sensitive species.
- Niagara Escarpment: bedrock features and habitat specialists.
- Interior swamps: ***refugia*** for native plants and animals, because a majority of the uplands have been cleared and intensively developed.
- Critical nesting, wintering, and stopover habitats for birds.
- Miscellaneous features: mesic hardwood forests, pine-oak forests, stream corridors, undeveloped lakes, surrogate grasslands, rare species populations not covered elsewhere.

Management Opportunities for Important Ecological Features of the Central Lake Michigan Coastal Ecological Landscape

Natural communities, waterbodies, and other significant habitats for native plants and animals have been grouped together as "ecological features" and identified as management opportunities when they

- occur together in close proximity, especially in repeatable patterns representative of a particular ecological landscape or group of ecological landscapes;
- offer compositional, structural, and functional attributes that are important for a variety of reasons and that may not necessarily be represented in a single stand;
- represent outstanding examples of natural features characteristic of a given ecological landscape;
- are adapted to and somewhat dependent on similar disturbance regimes;
- share hydrological linkage;
- increase the effective conservation area of a planning area or management unit, reduce excessive edge or other negative impacts, and/or connect otherwise isolated patches of similar habitat;
- potentially increase ecological viability when environmental or land use changes occur by including environmental gradients and connectivity among other important management considerations;
- accommodate species needing large areas or those requiring more than one type of habitat;
- add habitat diversity that would otherwise not be present or maintained; and
- provide economies of scale for land and water managers.

A site's conservation potential may go unrecognized and unrealized when individual stands and habitat patches are managed as stand-alone entities. A landscape-scale approach that considers the context and history of an area, along with the types of communities, habitats, and species that are present, may provide the most benefits over the longest period of time. This does not imply that all of the communities and habitats associated with a given opportunity should be managed in the same way, at the same time, or at the same scale. We, instead, suggest that planning and management efforts incorporate broader management consideration and address the variety of scales and structures approximating the range of natural variability in an ecological landscape—especially those that are missing, declining, or at the greatest risk of disappearing over time.

Both ecological and socioeconomic factors were considered when determining management opportunities. Integrating ecosystem management with socioeconomic activities can result in efficiencies in the use of land, tax revenues, and private capital. This type of integration can also help to generate broader and deeper support for sustainable ecosystem management. Statewide integrated opportunities can be found in Chapter 6, "Wisconsin's Ecological Features and Opportunities for Management."

Significant ecological management opportunities that have been identified for the Central Lake Michigan Coastal Ecological Landscape include

- Lake Michigan shoreline features
- Lower Green Bay
- Lower Wolf River corridor
- Niagara Escarpment
- Interior swamps
- Habitat for migratory, wintering, and nesting birds
- Miscellaneous features: river and stream corridors; remnant sugar maple-American beech forests; clay ravines; lakes; ephemeral ponds; scattered sensitive species habitats

Natural communities, community complexes, and important habitats for which there are management opportunities in this ecological landscape are listed in Table 8.2. Locations where there are examples of some of these important ecological features and management opportunities occur are on the "Ecologically Significant Places within the Central Lake Michigan Coastal Ecological Landscape" map in Appendix 8.K at the end of this chapter.

Great Lakes ridge-and-swale complex. Open sedge-dominated swale is flanked by sandy ridges supporting a mixed conifer-hardwood forest. Such sites are extremely important to birds (breeders and migrants), and many other native species. Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.

Lake Michigan Shoreline Features

In the Central Lake Michigan Coastal Ecological Landscape, most of the immediate Lake Michigan shoreline is upland and has undergone extensive development to serve agricultural, residential, recreational, and urban-industrial uses. Cities now exist at the mouth of virtually every major river and stream entering Lake Michigan, and extensive filling of coastal wetlands has occurred in some areas.

Among the Lake Michigan shoreline features meriting special attention are the coastal ridge-and-swale complexes (e.g., at Point Beach, Woodland Dunes, and Bender Road), the alvar habitats near Red Banks (which are unique and known to support rare species, including rare plants), and clay bluffs and ravines that have retained relatively intact native vegetation. Beach and dune complexes support many plants that occur in no other habitats. Marshes and other wetlands along larger rivers such as the Kewaunee, East Twin, West Twin, and Milwaukee should also receive rare plant (and animal) surveys.

Interdunal wetland, Kohler-Andrae State Park in Sheboygan County. Photo by Thomas Meyer, Wisconsin DNR.

Table 8.2. *Natural communities, aquatic features, and selected habitats associated with each ecological feature within the Central Lake Michigan Coastal Ecological Landscape.*

Ecological features[a]	Natural communities,[b] aquatic features, and selected habitats
Lake Michigan shoreline features	Interdunal Wetland Clay Seepage Bluff Great Lakes Beach Great Lakes Dune Great Lakes Ridge-and-Swale Complex Lake Michigan
Lower Green Bay	Alder Thicket Shrub-carr Northern Sedge Meadow Southern Sedge Meadow Emergent Marsh Submergent Marsh Green Bay (Great Lake)
Lower Wolf River corridor	Floodplain Forest Southern Mesic Forest Tamarack (Poor) Swamp Alder Thicket Shrub-carr Northern Sedge Meadow Southern Sedge Meadow Surrogate Grassland Emergent Marsh Emergent Marsh - Wild Rice Submergent Marsh Warmwater River Warmwater Stream
Niagara Escarpment	Southern Dry-Mesic Forest Southern Mesic Forest Cedar Glade Algific Talus Slope Alvar Bedrock Glade Dry Cliff Moist Cliff
Interior swamps	Northern Wet-Mesic Forest Northern Wet Forest Northern Hardwood Swamp Hardwood Swamp Alder Thicket Bog Relict Inland Lake
Habitat for migratory, wintering, and nesting birds	Surrogate Grassland Great Lakes Beach Green Bay, Lake Michigan and their shorelines Major River Corridors

Continued on next page

Table 8.2, *continued*.

Ecological features[a]	Natural communities,[b] aquatic features, and selected habitats
Miscellaneous features	Northern Mesic Forest Northern Dry-Mesic Forest Ephemeral Pond Bedrock Glade Coldwater Stream Coolwater Stream Impoundment/Reservoir Inland Lake

[a]An "ecological feature" is a natural community or group of natural communities or other significant habitats that occur in close proximity and may be affected by similar natural disturbances or interdependent in some other way. Ecological features were defined as management opportunities because individual natural communities often occur as part of a continuum (e.g., prairie to savanna to woodland, or marsh to meadow to shrub swamp to wet forest) or characteristically occur within a group of associated community types (e.g., lakes within a forested matrix) that for some purposes can more effectively be planned and managed together rather than as separate entities. This does not imply that management actions for the individual communities or habitats are the same.

[b]See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for definitions of natural community types.

Public ownership is limited within this ecological landscape but includes several properties along Lake Michigan that encompass complexes of outstanding natural features, such as Point Beach State Forest, Kohler-Andrae State Park, and Harrington Beach State Park. Other important owners and stewards of Lake Michigan shoreline properties include the University of Wisconsin-Green Bay, several counties, local land trusts, and other NGOs.

Lake Michigan offers numerous opportunities to improve water quality and various habitats, protect and restore natural communities, and restore impaired ecological functions. In the Central Lake Michigan Coastal Ecological Landscape, many of these opportunities are centered on lower Green Bay, the largest bay on Lake Michigan and an area of high ecological significance. A number of initiatives are ongoing (see below) to restore and improve wetland vegetation along the Great Lakes shores and to benefit the fish and other aquatic life in Lake Michigan and Green Bay.

The general orientation of the entire shoreline is north-south, and as a result, large numbers of migrating birds move along the Lake Michigan coast in spring and fall. Establishing secure stopover sites for these migrants is a need in this heavily developed ecological landscape. Lake Michigan and its shoreline environments also provide important wintering areas for waterfowl, gulls, and some raptors (e.g., Snowy Owls). See the opportunities listed under "Habitat for Migratory, Wintering, and Nesting Birds" below.

Point Beach State Forest, Manitowoc County. Photo by Eric Epstein, Wisconsin DNR.

Management Opportunities, Needs, and Actions

- High levels of protection are warranted for sensitive Great Lakes coastal features such as ridge-and-swale complexes, beach and dune communities, estuarine wetlands, undisturbed clay bluffs and ravines, and shoreline forests.
- Of paramount importance to the long-term viability of coastal wetlands is the protection and, where needed, restoration of site hydrology.
- Collect more detailed descriptive information on the composition and structure of Lake Michigan's coastal communities, assess their condition and management needs, and prioritize the conservation actions needed to sustain them.
- Because so much of this ecological landscape is privately owned, inventory projects are more likely to achieve broad support if provisions to contact landowners are planned up front by the project coordinators. When local residents do the contact work, it may go much faster and with a greater likelihood of success than when officials representing government agencies make the contacts.
- Establish adequate stopover sites along the coast for migratory birds and other species.
- Monitor use of shoreline habitats by birds, fish, herptiles, invertebrates, and plants and identify habitat protection opportunities and needs. Develop and implement a plan to protect critical shoreline habitats with interested parties, including private individuals, NGOs, academic institutions, and federal, state, and local governments.

- The Wisconsin DNR's process of property master planning creates opportunities to update old information, examine adequacy of existing property boundaries, and engage with various partners on ecological and economic topics of mutual interest and concern.
- Develop comprehensive property master plans for State properties bordering Lake Michigan. Most existing plans are now quite old (in some cases, they don't exist).
- Develop a monitoring program to track known infestations of invasive species and identify populations of new invasives along the Lake Michigan shore, especially at river mouths and in harbors. Couple this with means of limiting new introductions and of containing or controlling them as quickly as possible.
- Identify, assess, and protect areas in Lake Michigan used by native fish for spawning, including estuaries, coastal marshes, reefs, and bays.
- Monitor sensitive coastal features and work with partners to ensure that future use and expanded development do not further impair or degrade them.
- Communicate with other Great Lakes states and provinces to share information on coastal features and processes; refine species, community, and habitat status determinations; assess protection and management needs; and develop a prioritized protection plan.
- Avoid siting industrial wind facilities in areas used heavily by migratory birds and bats. This includes areas that are several miles offshore and that are now known to be heavily used by migrating and wintering waterbirds.
- Reduce inputs of persistent toxic substances to Lake Michigan from known sources.
- Improve sediment quality by reducing pollutant concentrations so that if dredging is necessary, disposal of dredge spoils is not restricted because of their existing contaminant loads.
- Reduce inputs of nutrients and sediments into Lake Michigan via tributary streams by encouraging enrollment by private landowners into programs aimed at soil conservation and management and streambank protection. These include the Conservation Reserve Program and ***Wetland Reserve Program***.
- Based on an evaluation of environmental impacts associated with solid piers and rock groin structures in Lake Michigan, develop an action plan to eliminate or mitigate negative impacts from these structures to coastal processes essential to maintaining the geological integrity and biological diversity of shoreline habitats over time.
- Conduct periodic lake trout and lake-wide fish assessments as needed at the mid-lake refuge in Lake Michigan (a reef 40 miles east of Sheboygan that historically was a major lake trout spawning area and is now closed to commercial and recreational fishing) to characterize and evaluate the lake trout population.
- Using the lake sturgeon habitat assessment for the Sheboygan River, identify and implement actions aimed at enhancing remnant lake sturgeon populations and improving available habitat.

Lower Green Bay

Lower Green Bay and the mouth of the Fox River comprise a highly disturbed but rich ecosystem that includes the shallow waters of the lower bay, small islands that support significant rookeries of fish-eating birds, and extensive coastal marshes and other wetland communities now concentrated west of the Fox River's mouth and along the bay's west shore. Important marsh complexes of the lower bay include Long Tail Point, Little Tail Point, Point Au Sable, and Peats Lake, all of which are heavily used by migratory and resident waterfowl and other birds. In recent decades, the marsh vegetation has undergone a drastic shift in dominance from native cat-tails, bulrushes, arrowheads, and bur-reeds to highly invasive, nonnative species such as common reed, purple loosestrife, and narrow-leaved and hybrid cat-tails. The lower bay formerly supported highly significant commercial fisheries. More recently, there has been an emphasis on sport fishery development.

The bay has been adversely affected by industrial pollution, extensive wetland filling in and around the city of Green Bay, serious incursions by invasive plants and animals, and intensive agricultural and urban development on the adjoining uplands. Green Bay's importance as a heavily used port makes it likely that introductions of invasive species will continue into the foreseeable future.

Public owners of lands along and near lower Green Bay include the Wisconsin DNR and various units of the Green Bay West Shores Wildlife Area and Red Banks Alvar State Natural Area, which was established with the help of many partners, including UW-Green Bay, the Northeast Wisconsin Land Trust, and The Nature Conservancy, to protect a biologically rich stretch of the Niagara Escarpment and adjoining alvar habitat. The City of Green Bay owns parklands and a wildlife sanctuary on the lower bay, and UW-Green Bay is partial owner of the wetlands at Point au Sable. Brown County owns the Cat Island chain in the lower bay, and Brown, Door, and Kewaunee counties all have small holdings on the east side of Green Bay. The U.S. Army Corps of Engineers may own at least some of the artificial islands created by dredge spoil disposal in lower Green Bay.

Because lower Green Bay is a dynamic ecosystem that experiences frequent, intense, and sometimes unpredictable natural and human disturbances, future changes are sure to come. One recent dramatic disturbance to the lower bay was the virtual destruction of the Cat Islands, a chain of small islands that served as barriers that protected the shallow bay waters and adjoining coastal wetlands and provided nesting, resting, and foraging habitat for many species of resident and migratory waterbirds. High water levels, severe storms, and ice action combined to destroy the Cat Island chain in the 1970s. The University of Wisconsin Sea Grant Institute and federal agencies, Brown County, many private partners, and the Wisconsin DNR are working to design a plan for rebuilding the islands and restoring coastal wetlands (UW-SGI 2015).

Management Opportunities, Needs, and Actions

- Protect and conserve wetland complexes with high ecological values and which provide important social benefits. Various strategies and mechanisms, including acquisition, easements, and incentive programs, have been developed to accomplish this and are offered by public agencies, some NGOs, and various public-private partnerships.
- Prevent further loss of high quality wetland communities through filling, draining, or the conversion of one wetland type to another.
- Continue work on the control of invasive species that are problems now, such as common reed, narrow-leaved cattail, reed canary grass, and purple loosestrife.
- Implement programs to restore natural shorelines and connections between Green Bay and adjoining wetlands.
- Monitor the use of Green Bay by birds and fish, paying special attention to waterfowl, fish-eating colonial birds, and other organisms (including some fish) thought to have special value as environmental indicators.
- Continue to research and develop programs aimed at establishing self-sustaining, balanced, and diverse fish assemblages. One means of doing this is to improve spawning habitat in lakes, rivers, streams, and wetlands within the local watersheds of the lower bay to increase populations of important game fish, forage fish, and rare fish species.
- Develop a monitoring program to identify new invasives. Couple this with means of limiting new introductions and containing or controlling them as quickly as possible.
- Prior to removing dams to allow free passage of fish and other native species, consider the potential for invasive species or diseases moving upstream from Lake Michigan.
- Continue to map, type, and monitor the coastal wetlands over cycles of low and high lake levels. Document vegetation types and their composition and extent.
- Determine the feasibility of restoring wetlands along Green Bay's west shore that had been farmed or developed during periods of low water levels. Restorations of this sort can help mitigate habitat losses to fish and wildlife during periods of high water in the bay.
- Work toward the maintenance and restoration of hydrological functions on public lands by mimicking natural hydrological regimes within an ***adaptive management*** framework. The latter is critical because of the uncertainties inherent in knowledge of future changes to the dynamic bay ecosystem.

Point au Sable interior lagoon, lower Green Bay in Brown County. Photo by Eric Epstein, Wisconsin DNR.

Restoration of islands and wetlands in Lower Green Bay. Visible in this oblique aerial photo are the Cat Island Chain, mouth of the Fox River, City of Green Bay, the main shipping channel, and Kidney Island (in the background). Photo by Steve Seilo.

- Monitor "submerged" islands and the break in Long Tail Point to determine if any of the islands and points are reestablishing themselves during low water periods.
- Achieve and maintain water quality that protects both human health and the ecosystem from the adverse effects of toxic substances on shoreline and aquatic vegetation, fish, aquatic life, and wildlife utilizing the aquatic resources.
- Reduce phosphorus and sediment delivery to waterways from farms and construction sites.
- Decrease stormwater pollution through education, enforcement, monitoring, and regulation. Improve enforcement of existing storm water ordinances by local governments.

- Participate in the Fox-Wolf Basin Nonpoint Source Pollution Abatement Initiative (the initiative integrates existing Wisconsin DNR programs with other agencies, local governments, and public and private sector interests to guide water quality restoration and protection efforts over the long term) with the goals of restoring balanced aquatic ecosystems and protecting waterbodies from future polluted runoff.
- Continue remediation of ***polychlorinated biphenyls*** (PCBs) in the Fox River and Green Bay using the Natural Resources Damage Assessment (NRDA) process, and evaluate the changes in fish and wildlife PCB concentrations.
- Identify and prioritize additional habitat improvement and restoration projects, whether as part of the Natural Resource Damage Assessment process, or other programs.
- Work with partner groups and other agencies to design, support, and implement the Cat Island Chain restoration project.
- Where it is not possible to avoid wetland loss, mitigation and restoration efforts should be considered to provide habitat for wildlife and fish.

Lower Wolf River Corridor

In the western part of this agriculturally dominated ecological landscape, the vast majority of what remains for natural vegetation is associated with the Wolf River floodplain. Significant acreages of Floodplain Forest, Shrub-carr, and Emergent Marsh are present as are smaller but still significant areas of Southern Sedge Meadow and Southern Mesic Forest.

The sustainable management of Floodplain Forests has been and will probably continue to be difficult. The natural disturbance regime on which this community is dependent has been altered by dams and ditches, and the impacts over time are not well understood. Opening of the canopy, whether by natural means such as windstorms, or human actions, such as logging, can expedite the spread of invasive plants and facilitate the dominance of species such as reed canary grass and box elder. Forest management plans need to consider impacts beyond the stand level because habitats used by some of the least common residents of floodplain forests can be easily lost and are difficult to replace. Recent information on ***old-growth forest*** and ***old forest*** considerations for bottomland hardwoods is available in a Wisconsin DNR handbook (WDNR 2008c).

In many areas, the banks of the Wolf River and its larger tributaries have been rip-rapped in the past to stabilize banks and in recent years to enhance spawning habitat for the lake sturgeon. At some point, this may have detrimental impacts to habitats needed by other aquatic species, including other sensitive fish.

Along the lower Wolf River corridor and many other lowland hardwood forests, the American elm, formerly an important canopy component of many lowland hardwood forests, has been decimated by Dutch elm disease and persists only in the seedling, sapling, and small tree stages. Now the exotic insect emerald ash borer threatens all of our native ash species.

In some areas, Floodplain Forest communities have been, and continue to be, converted to other wetland types. This has often been done to benefit common and widespread waterfowl such as the Canada Goose and Mallard. However, this also represents the loss of habitat that is significant, sometimes critical for many other species (e.g., for Prothonotary Warbler and Red-shouldered Hawk), and there is no program that is seeking to increase the amount of Floodplain Forest to make up for or better quantify these habitat conversion losses. At a minimum, what is needed is a statewide assessment of "non-marsh" communities, before proceeding with more conversions.

Management Opportunities, Needs, and Actions:

- The entire floodplain of the lower Wolf River merits protection because this ecosystem supports numerous rare or otherwise sensitive species and everything around it is now heavily developed.
- Develop management techniques and philosophies for forested floodplain systems that do not result in ecosystem simplification and the loss of tree species that are deemed to be of low value.
- Assess the local and landscape impacts of continuing conversion of Floodplain Forest to marsh or open water habitats.
- Monitor for invasive species, including the emerald ash borer, and select a suite of sensitive species for monitoring that inhabit and are wholly or partially dependent on extensive forested floodplain systems.
- Lack of tree regeneration has been problematic in many Floodplain Forests. Reed canary grass is a significant problem, and lack of ability to control it is an obstacle to

Forested floodplain of the Wolf River, oxbow lakes occupying abandoned meander channels. Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

regenerating trees in Floodplain Forests. Current methods are either uncertain or unreliable and may result in stand simplification.

- Develop a comprehensive new master plan for the existing State properties along this stretch of the Wolf River that considers the entire system.
- Old forest and old-growth forest management guidelines are available for "bottomland hardwoods" and should be considered for any stand in which active management is proposed (WDNR 2008c).
- Create an up-to-date wetland information resource accessible to all agencies, to maintain information regarding delineated wetlands, wetland community types, wetland regulations, and plans that provide goals, objectives, and priorities. Involve all of the various stakeholders.
- Continue the program of lake sturgeon management in ways that do not cause the loss of mussels, other invertebrates, and other fish species.
- Maintain the floodplain areas along the Wolf River to protect multiple habitat values for riverine and upland species. Connect large blocks of older floodplain forest to benefit the numerous Species of Greatest Conservation Need that rely on this habitat.
- Implement plans to address the emerald ash borer (WDATCP and WDNR 2014).
- Wisconsin DNR should assist the county in identifying drain tile connections from septic systems and milk-house wastes to surface waters and facilitate the corrections.
- The Wisconsin DNR should also assist and encourage municipalities to adopt a stormwater management ordinance for water quantity and quality, including a snow disposal policy.

Niagara Escarpment

The Niagara Escarpment is a prominent geological feature that crosses several ecological landscapes and outcrops intermittently north and east of the city of Green Bay and to the east of the Fox River south toward Lake Winnebago. Composed of Silurian dolomite, the escarpment harbors unique microhabitats and provides habitat for many rare and highly specialized species. Rare land snails, several of which are globally rare, are of especially high significance here.

A critical management issue centers on protection of site hydrology and ensuring that the escarpment habitats are neither dried out nor inundated. Removal of timber to create viewsheds or for other purposes can lead to habitat desiccation, loss of the leaf litter needed by the rare snails, and destabilization of steep slopes on or around the escarpment. Detailed management plans are needed for each site judged to be of high ecological significance, and, insofar as is feasible, sites should be connected via additional protection or restoration.

Some of the oldest trees documented in Wisconsin grow on the Niagara Escarpment. These can provide clues to past climate conditions and the stability of key microhabitats over timescales of centuries.

Because most of the lands on and around the escarpment are privately owned, conservation will require innovative partnerships and cooperative management agreements.

Management Opportunities, Needs, and Actions:

- Continue efforts to protect, manage, and monitor rare species and the unusual habitats that are associated with the Niagara Escarpment.
- Continue protection efforts at escarpment sites of known value such as Red Banks and Greenleaf.
- The Alvar site near Red Banks is the only potentially viable preservation site for Alvar in the state.
- Monitor populations of rare land snails and determine their long-term habitat needs.
- Survey and monitor caves for bats, which may use them as roosts, nurseries, or hibernacula.
- Continue efforts to protect, manage, and monitor rare species and the unusual habitats that are associated with the Niagara Escarpment.
- Convey the special values of the escarpment's ancient trees to landowners, foresters, and various property managers.
- Determine the research needed to develop effective management plans for escarpment sites. Protection of site hydrology and dispersal of rare species are just two of the problematic factors.
- Work with private landowners, highway departments, and utility companies on implementation of practices that will maintain viable habitat on the escarpment.
- Assess adequacy of existing inventories on the escarpment and develop plans to provide and upgrade missing, outdated, or obsolete information.

Interior Swamps

Away from the immediate shorelines of Lake Michigan and Green Bay, the eastern part of this ecological landscape is almost entirely dedicated to intensive agricultural use. The only extensive areas of natural vegetation occur within several large isolated wetlands in southern Door and eastern Kewaunee counties and at a few other locations nearby. Most of these wetlands are forested, with second-growth stands of swamp hardwoods, northern white-cedar, tamarack, and sometimes floodplain forest.

These lands are mostly in private ownership, and relatively few large tracts exist. Most of the forests, which tend to be swamp hardwoods or mixed swamps with some northern white-cedar and tamarack, have been cut repeatedly. At first glance, their condition seems highly variable.

Field surveys are needed for sites that appear from remote sensing data, information provided by local landowners and naturalists, or cursory windshield viewing to be the most ***ecologically intact***. Initially this could be done by air photo interpretation or GIS analysis. Contacting the relevant landowners for access permission would be the next step. If findings from field inventory supported further conservation efforts, identify an appropriate project lead and develop a protection and management plan.

Management Opportunities, Needs, and Actions:

- Inventory the interior swamps to identify stands that are relatively old and large, dominated by conifers (where appropriate), with minimal infestations of invasives, and hydrologically intact.
- Create ***buffers*** around large or otherwise ecologically significant sites that will minimize or eliminate excess inputs of sediments and nutrients from nearby agriculture lands, subdivisions, or villages.
- Identify sites in which the promotion and restoration of conifers such as northern white-cedar and tamarack is appropriate and feasible. If this is not feasible, determine why.
- Develop innovative means of working toward overall protection goals for forested wetlands with diverse groups of private landowners.
- Basic inventory is needed for many of these wetlands and is a necessary first step in determining conservation priorities.
- Relatively intact areas of upland forest within or adjacent to the large swamps would be protection priorities in many, if not most, situations.
- Protect large insular hardwood swamps, such as Kellner Lake and Holland Red Maple Swamp, from hydrological changes and fragmentation due to road construction and housing development.

Hortonville Bog viewed from the south, Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

Habitat for Migratory, Wintering, and Nesting Birds

The Lake Michigan shoreline is heavily used by migratory birds of many kinds, including waterfowl, loons, grebes, gulls, terns, shorebirds, raptors, and passerines. Many sites along the Lake Michigan shore are popular with birders because of the high diversity of birds and many rarities that can be observed there, but also of great significance are the large numbers of other taxa that use the shoreline, nearshore waters, and offshore waters. Providing and maintaining a sufficient variety and abundance of the habitats needed by these birds is a priority conservation goal. A corollary would be to ensure that developments along the coast and in the offshore waters do not negatively impact the welfare of migratory species during critical stages of their life history.

Certain birds, including waterfowl such as Long-tailed Duck, Red-breasted Merganser, Common Goldeneye, Greater Scaup, and the three scoter species, are almost entirely dependent (at least seasonally) upon large, deep waterbodies, including that part of Lake Michigan that forms the eastern boundary of the Central Lake Michigan Coastal Ecological Landscape, to provide suitable wintering and migratory habitat. Other waterfowl, including Bufflehead and Lesser Scaup (*Aythya affinis*), also make heavy use of Lake Michigan's waters during some times of the year.

Recent surveys of open water habitats in Lake Michigan have revealed that tens of thousands of diving ducks and other water birds are using offshore habitats (see Figure 8.13 for northern Lake Michigan offshore habitats), some of them as many as 10 miles from the coast (Mueller et al. 2010). Three waterfowl species comprised over 87% of the total waterfowl seen during the fall, winter, and spring surveys of 2010–11: Long-tailed Duck (47.6%), Red-breasted Merganser (29.9%), and Common Goldeneye (9.6%). The Red-breasted Merganser was found throughout all seasons and was distributed all along the coast. The Long-tailed Duck was found mostly in the fall and, in Wisconsin, mostly along the northern Lake Michigan coast. A total of 25,555 Long-tailed Ducks was seen on one day (2 November 2010). A winter waterfowl survey flight along the coast of Lake Michigan is conducted by Wisconsin DNR the first week in January every year (see the "Fauna" section).

A number of questions remain to be answered over the abundance and distribution of food resources, the movements of the birds within a season and between years, impacts of ice cover, and distance from shore at which significant bird activity occurs (winter and fall).

Major raptor banding stations have been in operation along Lake Michigan for many decades. Cedar Grove Hawk Research Station in Sheboygan County was established in the 1940s by staff from the Milwaukee Public Museum. In earlier years, banding had also occurred in the spring, and raptors were not the only taxa handled. No other banding station in North America has been operating continuously for as long. The other banding stations are Little Suamico in

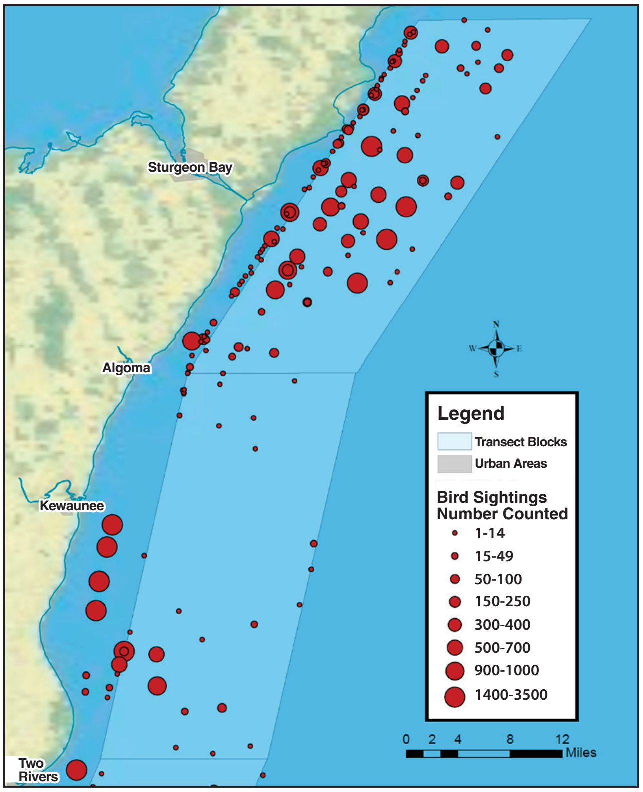


Figure 8.13. *Concentration of waterfowl and waterbirds along the northern Lake Michigan coast during fall and winter 2010–11 (Mueller et al. 2010). Figure provided by William Mueller of Western Great Lakes Bird and Bat Observatory and Ginny Plumeau, Amy Wagnitz, and Cindy Burtley of Cedarburg Science LLC (BHE Environmental).*

southern Oconto County, north of Green Bay, and Woodland Dunes, a privately owned nature preserve in Manitowoc County. All three of these banding stations are now active primarily in the fall, when the flights of migrating raptors are the heaviest. Migratory bird use of Green Bay's west shore is known to be heavy for some taxa. Documentation should also be sought for migratory bird use of the Wolf River corridor.

Management Opportunities, Needs, and Actions

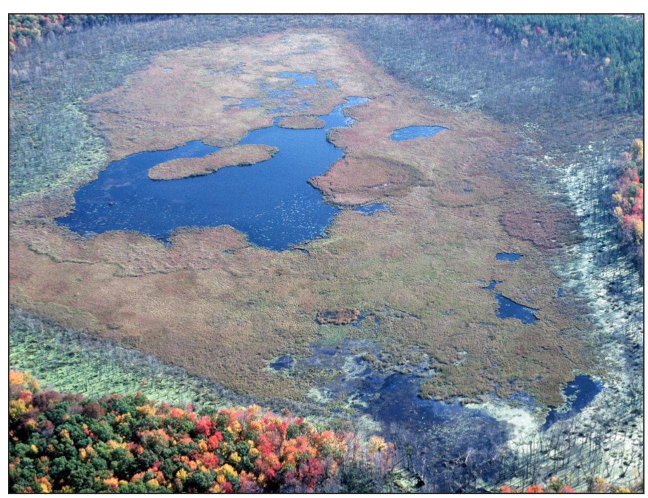
- Identify and characterize locations on Lake Michigan and along its shoreline that are heavily used by birds.
- Work with private and public partners to identify and protect additional shoreline forests, as these habitats are in very short supply, public land is scarce, and bird use during migration periods is heavy. Reforestation of some areas along the Lake Michigan shoreline that are used as migratory stopover sites for land birds is generally desirable.
- Assess the adequacy of protection offered by the current status of available conservation lands, including the waters of Lake Michigan.
- Identify habitat protection needs and opportunities, and work with local groups to implement protection plans.
- Supplement data included with Lake Michigan Important Bird Area write-ups (Steele 2007) with winter aerial surveys. Additional information is needed on stability and distribution of available food resources. The winter movements of birds as ice conditions and food availability shifts need more documentation.
- Areas of Lake Michigan as far as 10 miles (or more) from shore are being used during migration periods and in winter by tens of thousands of ducks and other waterbirds.
- Away from Lake Michigan, use of the Green Bay shore is known to be heavy for some groups of migratory birds. Additional documentation of migratory bird use is needed for the Wolf River corridor at the western edge of the ecological landscape.

Miscellaneous Features: River and Stream Corridors, Remnant Sugar Maple-American Beech Forests, Clay Ravines, Lakes, Ephemeral Ponds, Scattered Sensitive Species Habitats

This opportunity encompasses features that are not effectively captured within the other categories listed above. Some of these may be small in scale, isolated, or highly disturbed but may be important for various reasons, including lack of alternatives elsewhere, absence of important protected habitats locally, or exemplary condition (in which case a small, isolated stand may serve as a template for larger stands in need of restoration).

An updated and expanded inventory of natural communities, aquatic features, selected habitats, and certain rare species is needed for many parts of this ecological landscape not described in the previous opportunities.

Forest remnants, particularly those on rich soils composed of mesic hardwoods, have been greatly diminished from their historical abundance and need to be better represented in this ecological landscape. Size and connectivity need to be considered carefully as does stand condition, but the number



Shaky Lake. Photo by Eric Epstein, Wisconsin DNR.

of available conservation opportunities appears low. Recent information on old-growth and old forests is available in the Wisconsin DNR's publication *Old-growth and Old Forests Handbook* (WDNR 2008b).

If reforestation is considered as a means of sequestering carbon to combat global warming, the Central Lake Michigan Coastal Ecological Landscape would potentially offer many suitable locations. Historically, this ecological landscape was heavily forested, and the forest communities supported trees that had the potential to become very large and grow very old. Apart from this, there is presently a dearth of forested habitat and certain types of forest habitats in this ecological landscape. Providing additional resources dedicated to conservation would provide benefits to migrant birds along the Lake Michigan shoreline and to many habitat specialists, such as species with area sensitivities or specific structural needs. Social benefits in this heavily developed, densely populated area include the provision of aesthetic, recreational, and economic opportunities.

Additional buffering for some currently forested sites, such as those which have become reduced in size and severely isolated, is desirable to reduce or mitigate negative impacts of prevalent land uses or landscape patterns adjacent to existing forests, and in some cases, to increase effective forest size.

The ecological values of some of the potentially important stream corridors (other than the Wolf-Embarrass system) have not been well documented or widely disseminated. Several river systems are known to have high values in terms of possessing good quality natural communities, habitats, or aquatic species assemblages. Stream corridors needing additional assessment and documentation include the Kewaunee, East Twin, West Twin, Ahnapee, and Manitowoc rivers.

Clay ravines have not been well studied or sufficiently protected in Wisconsin. Some of these ravines contain seepages and are known to support rare or otherwise unusual plants and animals. Spatially, these are relatively small features, seldom covering more than a few tens of acres. Northern white-cedar is a common dominant in the ravines, which are often surrounded by active or abandoned farmland or subdivisions.

Undeveloped or otherwise valuable lakes should be identified and considered for protection. Most lakes in this ecological landscape are small and have been heavily developed. Those harboring unusual physical or chemical characteristics and known or suspected of supporting important biota should be considered for appropriate levels of protection, ideally by local trusts, lake districts, or private landowners.

Surrogate grasslands (formerly forested areas now dominated by nonnative cool season grasses) are locally important for declining breeding birds. Sample and Mossman (1997) ranked one site, "Brussels Grasslands" on the southern Door Peninsula, as an important landscape for native grassland birds. Sites such as this seem likely to shift in location, at least to some degree, because of changes in agricultural markets and practices and perhaps because of increased parcelization.

Management Opportunities, Needs, and Actions

- Identify and prioritize for protection forest remnants with the compositional, structural, and functional characteristics of each of the communities occurring within this ecological landscape. Stands with relatively high viability over the long-term and with minimum active management needs are the highest priority in the Central Lake Michigan Coastal Ecological Landscape.
- Other priorities would be forested sites that are large, relatively undisturbed, connected to other forest patches, and border rivers, streams, or lakeshores (including Lake Michigan and Green Bay).
- Undisturbed stands of all native forest communities, especially those that are well connected to other patches of forest (including more disturbed forests), are high priorities but will almost certainly be very rare.
- Create effective buffers around large interior wetlands such as the Black Ash Swamp, Duvall Swamp, Hortonville Bog, and the Kewaunee Fish and Wildlife Area. Establish connecting corridors between now-isolated forest patches where feasible. Eliminating or minimizing sediment and nutrient inputs would lessen the possibilities of negative floristic changes, such as those associated with the introduction of, or increase in, invasive plants, and the eventual loss of sensitive native habitat specialists.
- River and stream corridors should be evaluated for their overall integrity and ability to support native flora and fauna. Sites known to receive or suspected of receiving heavy use by migratory animals would be included here, especially on rivers that trend north-south, or that connect patches of habitat known to support important populations of native plants and animals.
- Aquatic specialists should be consulted on specific ecological values associated with lakes and littoral zones, especially those which remain entirely or mostly undeveloped, and/or which have retained good water quality and some intact littoral habitats.

Socioeconomic Characteristics

Socioeconomic information is summarized within county boundaries that approximate ecological landscapes unless specifically noted as being based on other factors. Economic data are available only on a political unit basis, generally with counties as the smallest unit. Demographic data are presented on a county approximation basis as well since they are often closely associated with economic data. The multi-county area used for the approximation of the Central Lake Michigan Coastal Ecological Landscape is called the Central Lake Michigan Coastal counties (Figure 8.14). The counties included are Waupaca, Outagamie, Brown, Kewaunee, Calumet, Manitowoc, Sheboygan, and Ozaukee because at least 25% of each of these counties lies within the ecological landscape boundary.

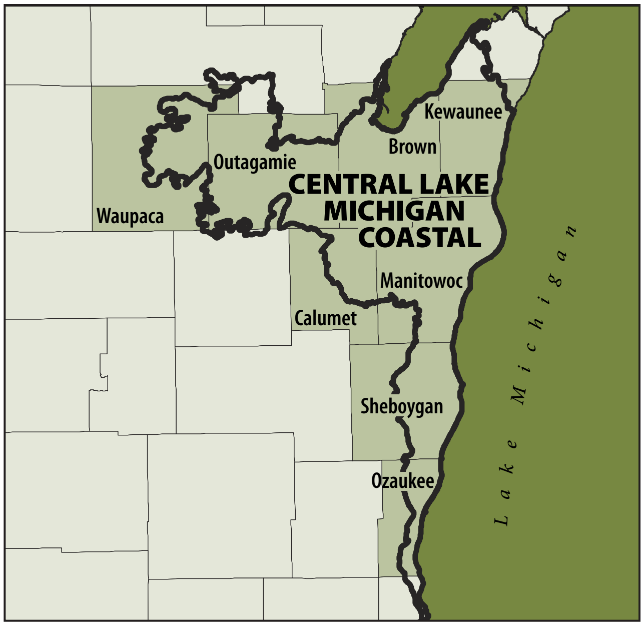


Figure 8.14. *Central Lake Michigan Coastal counties.*

History of Human Settlement and Resource Use

American Indian Settlement

There is very early evidence of habitation in the Central Lake Michigan Coastal Ecological Landscape, beginning at the time of the Paleo-Indian Tradition more than 10,000 years ago and continuing to the time of Euro-American contact. The Aebischer site in Calumet County has yielded surficial finds of early Paleo-Indian fluted points, end scrapers, and engravers, interestingly made from nonlocal stone from northern Illinois and from around Prairie du Chien (Mason 1997).

The Hilgen Spring Park Mounds site in Ozaukee County was occupied potentially as early as during the early Woodland Tradition, approximately 2,500 years ago. This site had three conical mounds that contained burials of humans and dogs, diagnostic pottery, and other artifacts (Stevenson et al. 1997). The Bachman site was occupied somewhat later than Hilgen Springs (2,400 to 2,100 years ago). This site is interesting for a number of reasons, including the finds of bone and copper tools and diagnostic pottery. The evidence points to a reliance on hunting and gathering; however, seeds of domesticated sunflower and sumpweed were also found at this site (Stevenson et al. 1997). There are a few sites in this ecological landscape that show Mississipian affinities. Klug Island in Ozaukee County had artifacts that suggest both the Woodland Tradition with Mississipian influence (Green 1997).

There are also several sites that are clearly Oneota in character in the Central Lake Michigan Coastal Ecological Landscape (Overstreet 1997). At the time of Euro-American contact, the Ho-Chunk occupied much of the ecological landscape but were diminishing in numbers, possibly due to the advance of diseases introduced by Euro-Americans. The ancestral link between the Oneota people and Ho-Chunk has long been assumed, but there is little evidence to confirm this empirically (Mason 1988). Most experts consider it likely that the Oneota are the forbearers of the Ho-Chunk.

A wide variety of tribes inhabited this region during the turbulent 17th century. The Iroquois Wars of this era made Wisconsin a new home for several displaced tribes from farther east. They included the Menominee, Potawatomi, Ottawa, Miami, and Oneida. The Oneida continue to inhabit this region. The Oneida reservation in Wisconsin is located between Green Bay and the northern shore of Lake Winnebago in Outagamie and Brown counties; approximately three-quarters of the reservation lies within the Central Lake Michigan Coastal Ecological Landscape. As of 1998, combined reservation lands of the Oneida totaled 64,167 acres: 38,785 acres in the town of Oneida, 21,556 acres in the town of Hobart, and 3,826 acres in Green Bay (The Wisconsin Cartographer's Guild 1998). See "Statewide Socioeconomic Assessments" in Chapter 2, "Assessment of Current Conditions," for further discussion of the history of human settlement and resource use in Wisconsin.

Euro-American Contact and Settlement

During the 17th century, French fur traders, soldiers, and missionaries began arriving in this region. As a result of Euro-American contact with American Indian tribes, trading posts, missions, and forts were established along river routes and lakes. During the mid-1800s, however, American Indian tribes began ceding large areas of land to the government, and permanent Euro-American settlement began in earnest.

A wide variety of Euro-American immigrants originally settled in small communities throughout the Central Lake Michigan Coastal counties. Belgians, Poles, French, Dutch, Norwegians, and Germans are some of the more prominent immigrant groups to first make their home in this region of Wisconsin. Forty-seven percent of Wisconsin residents claim Germany as their first ancestry (The Wisconsin Cartographer's Guild 1998). Historically, German immigrant populations were not evenly dispersed and have been heavily concentrated in the eastern regions of the state, particularly in the Central Lake Michigan Coastal counties.

By 1900 Norwegian immigrants were the second largest foreign-born group in the state (Nesbit 2004). The majority had settled in the area stretching from Crawford County to Barron County, but there were also smaller settlements in Winnebago and Manitowoc counties (The Wisconsin Cartographer's Guild 1998).

Early Agriculture

Permanent Euro-American settlement began in the Central Lake Michigan Coastal counties in the 1840s and 1850s. In 1850 there were only about 678 farms and 20,039 people in the Central Lake Michigan Coastal counties (ICPSR 2007). By 1880 the number of farms in the Central Lake Michigan

Coastal counties had grown to 23,516 while the population had reached 1.69 million people. The population continued to grow thereafter, but farm numbers leveled off after reaching 24,600 farms in 1900 (Figure 8.15). By the start of the Great Depression in 1929, farm numbers had declined; farm numbers declined again following World War II as migration from rural to urban areas increased. Mechanization made it possible for the average size of farms to increase (Figure 8.16). That trend continued throughout much of the remaining 20th century.

Total value of all crops indicates the extreme influence of the Great Depression on agriculture. In 1910 all crops harvested in the Central Lake Michigan Coastal counties had an estimated total value of $20.5 million, which nearly tripled to $55.8 million by 1920 (ICPSR 2007). Total value of all crops in the Central Lake Michigan Coastal counties plummeted in 1930 ($29.3 million) and fell further in 1940 ($23.8 million). However, total values of crops in the Central Lake Michigan Coastal counties comprised 14.2% of total value in the state, even though these crops came from farms comprising only 10% of all Wisconsin farms. Central Lake Michigan Coastal county farms tended to be productive and more resilient to the ill effects of the Great Depression than many of their Wisconsin neighbors.

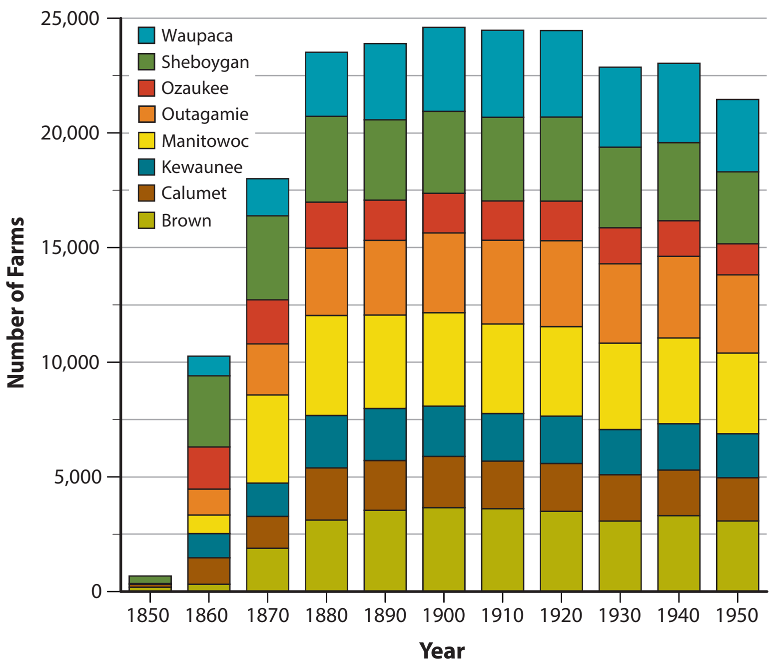


Figure 8.15. *Number of farms in Central Lake Michigan Coastal counties between 1850 and 1950 (ICPSR 2007).*

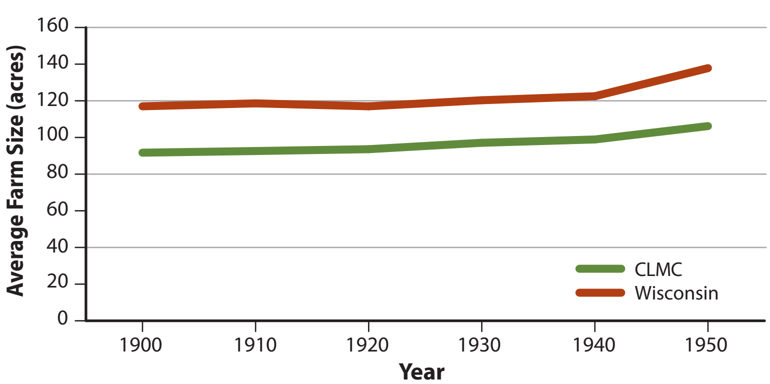


Figure 8.16. *Average farm size in Central Lake Michigan Coastal counties between 1900 and 1950 (ICPSR 2007).*

Over the early part of the 20th century, the type of farming in the Central Lake Michigan Coastal counties underwent some fundamental shifts as the dairy industry was established and Wisconsin became a national leader. The Central Lake Michigan Coastal counties were well suited to this type of agriculture. The 1910 federal agricultural census listed "cereals" as nearly 47% of the total value of all crops harvested in the Central Lake Michigan Coastal counties, but cereals comprised as little as 29.2% of total crop values in 1930, recovering only to 36.9% by 1940 (ICPSR 2007). Meanwhile, "hay and forage," associated with livestock farming, was only 29.5% of total value of crops harvested in the Central Lake Michigan Coastal counties in 1910 but had risen to 47% of total crop value by 1940.

Early Mining

While extensive mining of iron and copper did not occur in the Central Lake Michigan Coastal counties, Lake Michigan provided an important means of transportation for these commodities to national and international markets.

Early Transportation and Access

In 1673 Marquette and Jolliet established the first route across Wisconsin from Green Bay to the Mississippi River via the Fox and Wisconsin rivers. Early Euro-American settlers to the region found an extensive network of American Indian trails throughout the territory. With rapid Euro-American settlement growth following the end of the Black Hawk War in 1832, those trails were widened into roads suitable for ox carts and wagons (Davis 1947). A system of military roads was developed in Wisconsin around the same time, connecting key cities and forts with one another. The Fort Howard Road was built through the Central Lake Michigan Coastal Ecological Landscape from Milwaukee to Green Bay at the end of the 1830s and another military road from Green Bay to Portage was built at about the same time. By 1870, however, the importance of railroads had caused roads to become of secondary importance.

Several railroads stretched from southern or western Wisconsin into the Central Lake Michigan Coastal counties. One line of importance ran from Sheboygan to Fond du Lac and the Green Bay and Western Line connected Green Bay to

New London (Austin 1948). The Big Falls Railway Company also operated in this region from 1883 to 1893. See "Statewide Socioeconomic Assessments" in Chapter 2, "Assessment of Current Conditions," for further discussion of the history of transportation in Wisconsin.

Early Logging Era

The earliest concentrations of sawmills in or near the Central Lake Michigan Coastal counties were centered around Lake Winnebago. This region was not a major source of exported lumber during Wisconsin's logging days. It did, however, have substantial forest cover prior to Euro-American settlement. Generally, the forests here were logged for local use (e.g., to build towns and farm buildings, fuel, etc.), cleared, and the land converted to agricultural uses.

Resource Characterization and Use[1]

The Central Lake Michigan Coastal Ecological Landscape is the sixth largest ecological landscape in the state at 2,742 square miles. The population density is 212 people per square mile, which is second highest in the state. In spite of high human population density, the Central Lake Michigan Coastal Ecological Landscape has very little public land compared to other parts of the state. There is much less forest and grassland here and a higher proportion of agricultural and urban land. The number of visitors to state lands is very high, and there are several Land Legacy sites with high recreation potential.

Agriculture is very important to the economy of the Central Lake Michigan Coastal Ecological Landscape with an above average percentage of its land in farms. The Central Lake Michigan Coastal counties are very productive with the highest net income per farmed acre in the state. Agricultural land is some of the most valuable in the state, selling for over $4,400 per acre on average in 2007.

The Central Lake Michigan Coastal Ecological Landscape is an urbanized region with a very high density of roads and railroads and the highest number of cargo ports. Partly for this reason, these counties have the highest records of ground level ozone in the state. These counties are the state's largest users of water, from both ground and surface sources, but have one of the lowest amounts of surface water within their boundaries.

This region is a major producer of wind energy. In addition, with 58% of all of its surface water in rivers and streams, the Central Lake Michigan Coastal Ecological Landscape is also a major producer of hydroelectric power.

Little of the region is forested, and the Central Lake Michigan Coastal Ecological Landscape is not a major producer of primary wood products or woody biomass. The major forest types are bottomland hardwoods and maple-basswood.

[1]When statistics are based on geophysical boundaries (using GIS mapping), the name of the ecological landscape is followed by the term "ecological landscape." When statistics are based on county delineation, the name of the ecological landscape is followed by the term "counties."

The Land

Of the 1.74 million acres of land (excludes open water) that make up the Central Lake Michigan Coastal Ecological Landscape, only 19% is forested (USFS 2009). About 90% of all forested land is privately owned while 10% belongs to the state, counties, or municipalities. However, only 1.9% of the entire ecological landscape is in public ownership.

Minerals

In 2007 there were 27 mining establishments in the Central Lake Michigan Coastal counties (WDWD 2009). Employment in Brown, Calumet, and Manitowoc counties totaled 485 people with wages of $18.4 million. Of the eight counties, only Brown, Manitowoc, Sheboygan, and Waupaca have full disclosure of mining revenues (USCB 2012a). Seven of the eight Central Lake Michigan Coastal counties are currently engaged in some type of mineral extraction.

Water (Ground and Surface)

Water Supply

The data in this section are based on the Wisconsin DNR's 24K Hydrography Geodatabase (WDNR 2014b), which are the same as the data reported in the "Hydrology" section. However, the data are categorized differently here so the numbers will differ slightly. Surface water covers 22,975 acres (1% of total area) of the Central Lake Michigan Coastal Ecological Landscape. There are over 763 lakes that are at least 1 acre in size (totaling 6,567 acres, or 29% of total surface water) and no lakes over 500 acres in size. There are 9,899 acres of streams and rivers, the largest of which are the Fox, Wolf, and Manitowoc rivers. There are 161 dams impounding 6,891 acres of water.

Water Use

Each day 3.9 billion gallons of ground and surface water are withdrawn in the Central Lake Michigan Coastal counties (Table 8.3). About 98% of the withdrawals are from surface water. Of the 830,001 people that reside in these counties, 74% are served by public water sources and 26% are served by private wells (USGS 2010).

Brown, Waupaca, and Outagamie counties have the largest groundwater withdrawals while 56% of all surface water is withdrawn in Manitowoc County alone, with lesser amounts in Kewaunee, Brown, and Ozaukee counties (USGS 2010). The county with the largest water use is Manitowoc County, which accounts for 55% of the total in the eight county area. The greatest use of water, 94%, is for thermoelectric once-through power production.

Recreation

Recreation Resources

Land cover, land use patterns, and ownership partly determine the type of recreation that is available to the public. For instance, in the Central Lake Michigan Coastal Ecological Landscape there is far more agricultural and urban land

Table 8.3. *Water use (millions of gallons/day) in the Central Lake Michigan Coastal counties.*

County	Ground-water	Surface Water	Public Supply	Domestic[a]	Agriculture[b]	Irrigation	Industrial	Mining	Thermo-electric	Total
Brown	20.6	499.0	29.9	1.2	2.3	0.9	71.2	0.8	413.0	520.0
Calumet	5.3	2.0	4.5	0.6	1.2	0.4	0.7	0.0	–	7.0
Kewaunee	4.9	823.9	0.8	0.6	2.4	0.9	0.3	0.1	824.0	829.0
Manitowoc	7.8	2,135.0	11.7	1.6	2.2	0.9	2.2	1.1	2,123.0	2,143.0
Outagamie	13.3	87.4	14.7	1.5	2.0	0.6	47.8	1.2	33.0	101.0
Ozaukee	8.8	293.0	5.8	2.3	0.6	0.6	0.6	0.4	291.0	302.0
Sheboygan	5.2	3.3	2.4	0.8	1.9	0.2	3.1	0.1	–	9.0
Waupaca	17.6	1.7	5.8	1.6	1.3	8.7	1.7	0.3	–	19.0
Total	**83.5**	**3,845.3**	**75.7**	**10.2**	**13.8**	**13.3**	**127.5**	**3.8**	**3,685.0**	**3,929.0**
Percent of total	**2%**	**98%**	**2%**	**0%**	**0%**	**0%**	**3%**	**0%**	**94%**	

Source: Based on 2005 data from the U.S. Geological survey on water uses in Wisconsin counties (USGS 2010).
[a]Domestic self-supply wells.
[b]Includes aquaculture and water for livestock.

and less forest and grassland than in the rest of the state (see Chapter 3, "Comparison of Ecological Landscapes," and/or the map of "WISCLAND Land Cover (1992) of the Central Lake Michigan Coastal Ecological Landscape" in Appendix 8.K at the end of this chapter). This ecological landscape has the second highest percentage of urban and agricultural land in Wisconsin. Green Bay, the region's largest urban center, impacts much of the surrounding area with its suburban growth and cultural resources. Although acreage in inland waters is the second lowest in the state, much of the Central Lake Michigan Coastal Ecological Landscape borders Lake Michigan.

Compared to most other ecological landscapes, the Central Lake Michigan Coastal Ecological Landscape has a low proportion of public land. Although the amount of state land is low and the density of campgrounds is very low, the number of visitors to state lands in 2004 was higher than average (WDNR 2006a). The number of Land Legacy sites is above average and the number of sites with significant recreational potential is fourth highest in the state.

Supply

Land and Water. The Central Lake Michigan Coastal Ecological Landscape accounts for 5% of Wisconsin's total land area but only 1.3% of the state's acreage in water (see Chapter 3, "Comparison of Ecological Landscapes"). Although the area of inland surface waters is not large, Lake Michigan and its shoreline are extremely important to many forms of recreation, including boating, camping, fishing, and sightseeing. Away from Lake Michigan, streams and rivers make up 58% of the surface water area and lakes and reservoirs make up over 38% (WDNR 2014b).

Public Lands. Public access to recreational lands is vital to many types of recreational activity. Within the Central Lake Michigan Coastal Ecological Landscape, approximately 69,700 acres, or 4% of all land, is publicly owned (WDNR 2005a). This is significantly less than the statewide average of 19.5% public ownership. Of the 333,224 acres of ***forestland*** in the Central Lake Michigan Coastal Ecological Landscape, only 10% is in public ownership (USFS 2009).

State-owned lands and facilities are important to recreation in the Central Lake Michigan Coastal Ecological Landscape. There are approximately 3,000 acres of state forest at Point Beach; 1,800 acres in parks and recreation areas, including Harrington Beach, Two Creeks, and Kohler-Andrae State Parks; 870 miles of state trails, such as the Ahnapee and Fox River trails; and 44,600 acres of state-owned lands managed for wildlife and fisheries (WDNR 2005a). The largest of these are Navarino Wildlife Area, Killsnake Wildlife Area, and Brillion Wildlife Area, each of which covers over 5,000 acres.

Trails. Although the Central Lake Michigan Coastal counties have over 2,200 miles of recreational trails (see Table 8.4), they rank ninth (out of 16 ecological landscapes) in terms of trail density (miles of trail per 100 square miles of land). Compared to the rest of the state, there is a much higher density of hiking, road biking, and snowmobiling trails but a much lower density of ATV trails compared to the rest of the state (Wisconsin DNR unpublished data).

Campgrounds. There are 74 public and privately owned campgrounds that provide about 5,800 campsites in the Central Lake Michigan Coastal counties (Wisconsin DNR unpublished data). With 4% of the state's campgrounds, this ecological landscape ranks 11th (out of 16 ecological landscapes) in terms of the number of campgrounds and 13th in campground density (campgrounds per square mile of land).

Land Legacy Sites. The Land Legacy report has identified over 300 places of significant ecological and recreational importance in Wisconsin, and 17 are either partially or totally located within the Central Lake Michigan Coastal Ecological Landscape (WDNR 2006b). Three of them, the lower Wolf River Bottomlands, the Niagara Escarpment, and Point Beach and Dunes, are rated as having both the highest recreation and conservation significance.

State Natural Areas. The Central Lake Michigan Coastal Ecological Landscape also contains 2,535 acres of state natural areas (either partially or totally located within this ecological landscape) (Wisconsin DNR unpublished data). The largest state natural areas in this ecological landscape include the Hortonville Bog (1,299 acres, Outagamie County), Woodland Dunes (387 acres, Manitowoc County), Holland Red Maple Swamp (206 acres, Brown County), Point Beach Ridges (168 acres, Manitowoc County), and Kohler Park Dunes (154 acres, Sheboygan County). For more information, see the Wisconsin DNR's state natural areas web page (WDNR 2014d).

Demand

Visitors to State Lands. In 2006 there were an estimated 903,000 visitors to state recreation areas, state parks, and state forests in the Central Lake Michigan Coastal Ecological Landscape (Wisconsin DNR unpublished data). The majority, 58%, visited state parks, especially Kohler-Andrae State Park, while 42% of the total visited Point Beach State Forest.

Fishing and Hunting License Sales. Of all license sales, the highest revenue producers for the Central Lake Michigan Coastal counties were resident hunting licenses (55% of total sales) and resident fishing licenses (29% of total sales) (Wisconsin DNR unpublished data). Table 8.5 shows a breakdown of various licenses sold in the Central Lake Michigan Coastal counties in 2007. Brown County accounts for both the highest number of licenses sold and the highest revenue from sales. These counties account for about 9% of total license sales in the state. However, persons buying licenses in the Central Lake Michigan Coastal counties may travel to other parts of the state to use them.

Metropolitan Versus Nonmetropolitan Recreation Counties. Johnson and Beale (2002) classified Wisconsin counties according to their dominant characteristics, such as "nonmetro recreation county." This type of county is characterized by high levels of tourism, recreation, entertainment, and seasonal housing. None of the Central Lake Michigan Coastal counties are categorized as nonmetro recreation counties.

Recreational Issues

Results of a statewide survey of Wisconsin residents indicated that a number of current issues are affecting outdoor recreation opportunities within Wisconsin (WDNR 2006a). Many of these issues, such as increasing ATV usage, overcrowding, increasing multiple-use recreation conflicts, loss of public access to lands and waters, invasive species, and poor water quality, are common across many regions of the state. In the Central Lake Michigan Coastal Ecological Landscape, the limited amount of public land is a factor restricting recreational opportunities.

Silent Sports Versus Motorized Sports. Over the next decade, the most dominant recreation management issues will likely revolve around conflicts between nonmotorized and motorized

Table 8.4. *Miles of trails and trail density in the Central Lake Michigan Coastal counties compared to the rest of the state.*

Trail type	Central Lake Michigan Coastal (miles)	Central Lake Michigan Coastal (miles/100 mi^2)	Wisconsin (miles/100 mi^2)
Hiking	157	4.0	2.8
Road biking	321	8.2	4.8
Mountain biking	46	1.2	1.9
ATV: summer and winter	20	0.5	9.3
Cross-country skiing	220	5.6	7.2
Snowmobile	1,455	37.2	31.2

Source: Wisconsin DNR unpublished data.

Table 8.5. *Fishing and hunting licenses and stamps sold in the Central Lake Michigan Coastal counties, 2007.*

County	Resident fishing	Nonresident fishing	Misc. fishing	Resident hunting	Nonresident hunting	Stamps	Total
Brown	36,248	1,972	3,167	60,990	297	25,642	128,316
Calumet	10,404	340	2,132	13,767	24	4,205	30,872
Kewaunee	3,465	1,020	4,883	6,137	29	5,940	21,474
Manitowoc	11,747	631	3,078	20,342	86	10,959	46,843
Outagamie	23,869	712	2,033	42,497	200	12,109	81,420
Ozaukee	5,614	370	1,427	6,975	45	4,906	19,337
Sheboygan	16,631	1,176	4,282	25,346	181	14,625	62,241
Waupaca	17,570	5,027	779	29,244	214	8,102	60,936
Total	**125,548**	**11,248**	**21,781**	**205,298**	**1,076**	**86,488**	**451,439**
Sales ($)	**$2,873,091**	**$429,305**	**$361,534**	**$5,505,381**	**$154,142**	**$756,813**	**$10,080,266**

Source: Wisconsin DNR unpublished data, 2007.

recreation interests. From a silent-sport perspective, noise pollution from motorized users is one of the higher causes for recreation conflict (WDNR 2006a). Motorized recreational vehicles include snowmobiles, ATVs, motor boats, and jet skis. ATV use is especially contentious. ATV riding has been one of the fastest growing outdoor recreational activities in Wisconsin.

Timber Harvesting. A high percentage of statewide residents are concerned about timber harvesting in areas where they recreate (WDNR 2006a). Their greatest concern about timber harvesting is large-scale visual changes (i.e., large openings) in the forest landscape. Forest thinning and harvesting that creates small openings is more acceptable. Silent-sport enthusiasts as a group are the most concerned about the visual impacts of harvesting, while hunters and motorized users are somewhat less concerned.

Loss of Access to Lands and Waters. With increasing development along shorelines and continued parcelization of large blocks of land, there has been a loss of readily available access to lands and waters statewide, and to a small degree, that's also true here. This may be due to the concentration of new housing that has occurred with increased residential development and the closing of access to large areas of shoreline once open to the casual recreational user. Another element that may play into the perception of reduced access is a lack of information about where to go to find recreational opportunities. In a statewide survey, was highly ranked as a barrier to increased outdoor recreation (WDNR 2006a).

Agriculture

Farm numbers in the Central Lake Michigan Coastal counties decreased 39% between 1970 and 2002 (USDA NASS 2004). There were approximately 14,220 farms in 1970 and 8,711 in 2002. Between 1970 and 2002, average farm size increased from 146 acres to 179 acres (22%), which is much lower than the statewide average of 201 acres. The overall land in farms has steadily decreased since the 1970s (Figure 8.17). There were about 2 million acres of farmland in 1970, and by 2002, acreage was down to 1.6 million acres, a decrease of 25%. All eight counties had at least half of their land area in farms. Kewaunee and Manitowoc counties had the highest percentage, 79% and 67%, respectively.

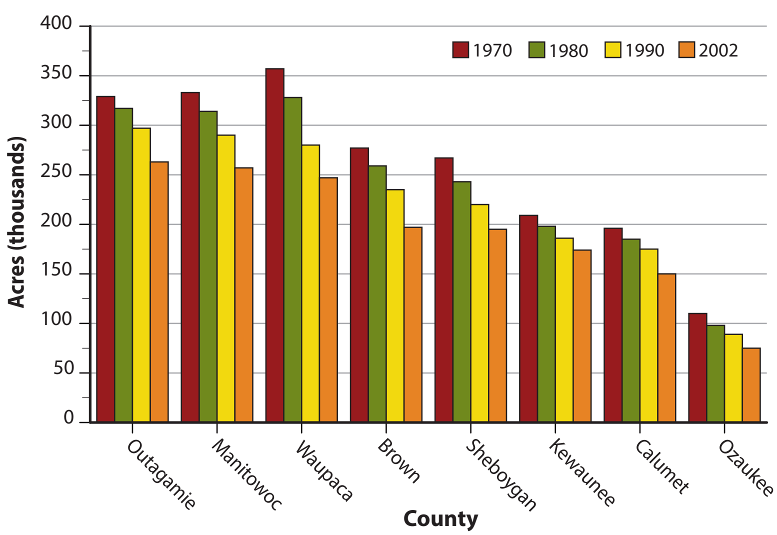


Figure 8.17. *Acres of farmland in the Central Lake Michigan Coastal counties by county and year (USDA NASS 2004).*

Agriculture is an important part of the economy of the Central Lake Michigan Coastal counties. In 2002 net cash farm income totaled $226 million, or an average of $145 per farm acre, much higher than the statewide average of $91 per acre (USDA NASS 2004). The market value of all agricultural products sold in the Central Lake Michigan Coastal counties was $859 million (10% of state total); 19% of this amount came from crop sales, while the remaining 81% was from livestock sales. Manitowoc, Brown, Outagamie, and Sheboygan counties all rank fairly high with respect to net farm income and market value of products sold. All four have a substantial dairy sector.

In 2007, 9,408 acres of farmland were sold, of which 86% stayed in agricultural use at an average selling price of $4,481, and 14% was diverted to other uses at an average sale price of $13,822 per acre (USDA NASS 2009). The Central Lake Michigan Coastal counties had some of the highest priced land in the state, both agricultural and developed.

Timber

Timber Supply

Based on 2007 U.S. Forest Service Forest Inventory and Analysis (FIA) data (USFS 2009), 19% (333,224 acres) of the total land area for the Central Lake Michigan Coastal Ecological Landscape is forested. This is only 2% of Wisconsin's total forestland acreage. Forestland is defined by FIA as any land with more than 17% canopy cover.

Timber Ownership. Of all timberland within the Central Lake Michigan Coastal Ecological Landscape, 90% is owned by private landowners (USFS 2009). The remaining 10% is owned by state and local governments (Figure 8.18). Timberland is defined as forestland capable of producing 20 cubic feet of industrial wood per acre per year that is not withdrawn from timber utilization (see the glossary in Part 3, "Supporting Materials," for a more detailed description of timberland).

Growing Stock and Sawtimber Volume. In 2007 there was approximately 562 million cubic feet of ***growing stock*** volume in the Central Lake Michigan Coastal Ecological Landscape, or 2.7% of total volume in the state. Most of this, 80%,

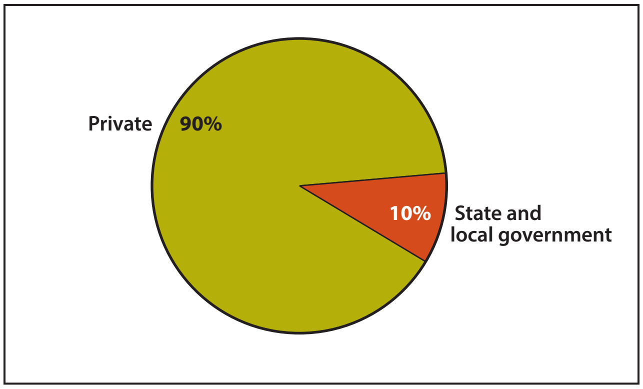


Figure 8.18. *Timberland ownership within the Central Lake Michigan Coastal Ecological Landscape (USFS 2009).*

was in hardwoods, similar to the proportion of hardwoods statewide, 74%. A similar proportion to growing stock, 77%, of ***sawtimber*** volume was in hardwoods. In comparison, the proportion of hardwood sawtimber statewide was 67% of total volume (USFS 2009).

Annual Growing Stock and Sawtimber Growth. Between 1996 and 2007, the timber resource in the Central Lake Michigan Coastal Ecological Landscape increased by 202 million cubic feet, or 56% (USFS 2007). Approximately 74% of this increase occurred in hardwood volume. Sawtimber volume increased by 631 million ***board feet*** (61%). Most of this change, 74%, was in hardwoods and may have been partly a result of an increase in timberland acreage. Between 1996 and 2007, acreage increased from 276,310 to 328,606 acres, or 19%. Statewide, timberland acreage increased by only 3% during the same time period.

Timber Forest Types. According to Forest Inventory and Analysis data (USFS 2009), the predominant forest type groups in terms of acreage are bottomland hardwoods (39%) and maple-basswood (29%), with smaller amounts of spruce-fir, oak-hickory and aspen-birch (see Appendix H, "Forest Types That Were Combined into Forest Type Groups Based on Forest Inventory and Analysis (FIA) Data," in Part 3, "Supporting Materials"). Acreage is predominantly in the sawtimber and pole size classes (47% and 42%, respectively) with only 9% in seedling and sapling classes (Table 8.6).

Timber Demand

Removals from Growing Stock. Timber production is not an important economic enterprise in the Central Lake Michigan Coastal Ecological Landscape, accounting for less than 3% of the growing stock volume on timberland in Wisconsin. Average annual removals from growing stock for the ecological landscape were 2.6 million cubic feet, or less than 1% of total statewide removals (349 million cubic feet) between 2000–2002 and 2005–2007 (USFS 2009) (see the "Socioeconomic Characteristics" section in Chapter 3, "Comparison of Ecological Landscapes" in Part 1 of the book). Average annual removals-to-growth ratios vary by species as can be seen in Figure 8.19. Growth exceeds removals for most species with the exception of quaking aspen (*Populus tremuloides*). Note that many of the species represented in Figures 8.19 and 8.20 are wetland associates.

Removals from Sawtimber. Less than 3% of the sawtimber volume on timberland in Wisconsin is in the Central Lake Michigan Coastal Ecological Landscape. Average annual removals from sawtimber were 6.8 million board feet, or less than 1% of total statewide removals (1.1 billion board feet) between 2000–2002 and 2005–2007 (USFS 2009). Average annual removals-to-growth ratios vary by species, as can be seen in Figure 8.20.

Price Trends

In the Central Lake Michigan Coastal counties, sugar maple, northern red oak, red maple, and white oak were the highest priced hardwood sawtimber species in 2007 (WDNR 2008a). Eastern white pine was the most valuable softwood timber species. Sawtimber prices for the year 2007 were generally lower for softwoods and higher for hardwoods compared to the rest of the state. For pulpwood, red pine was the most valuable. Pulpwood values in the Central Lake Michigan Coastal counties were generally lower than the statewide average.

Infrastructure

Transportation

The transportation infrastructure of the Central Lake Michigan Coastal Ecological Landscape is much more developed than in the rest of the state. For instance, road mile density is 33% higher (WDOA 2000), railroad density is 86% higher (WDOT 1998), and runway density is 35% higher than the state as a whole (WDOT 2012) (Table 8.7).

There are seven airports in the Central Lake Michigan Coastal Ecological Landscape, including two primary regional airports in Appleton (Outagamie County Regional Airport) and Green Bay (Austin Straubel International Airport). These two airports handle 13% of all passenger flights in the state (WDOT 2012). There are also four shipping ports in the Central Lake Michigan Coastal Ecological Landscape: a gateway port in Green Bay, two diversified cargo ports in Manitowoc and Sheboygan, and one limited cargo port in Port Washington (WCPA 2010).

Renewable Energy

Hydroelectric and wind power generation are important elements of the energy economy of the Central Lake Michigan Coastal Ecological Landscape. This ecological landscape has 2.5% of statewide woody biomass, generates 8.5% of the state's hydroelectric power and produces 6.6% of the state's corn crop. The Central Lake Michigan Coastal counties have three out of the 13 commercial wind facilities in the state but no ethanol plants.

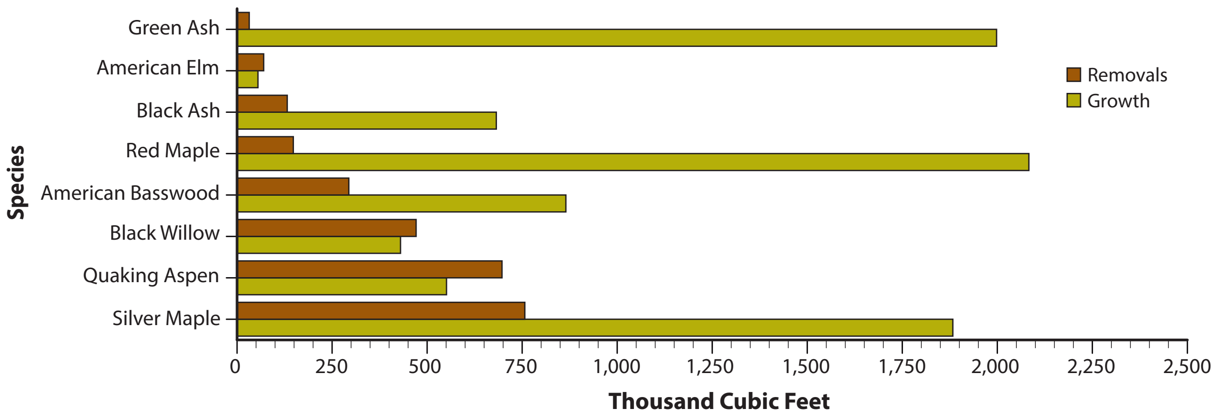


Figure 8.19. *Growing stock growth and removals (selected species) on timberland in the Central Lake Michigan Coastal Ecological Landscape (USFS 2009).*

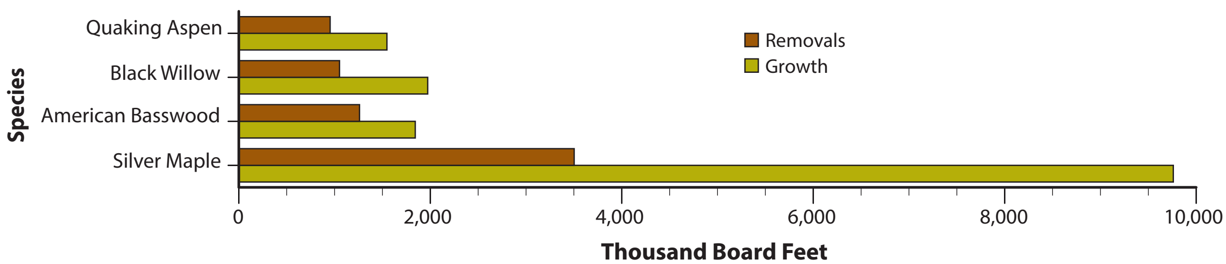


Figure 8.20. *Sawtimber growth and removals (selected species) on timberland in the Central Lake Michigan Coastal Ecological Landscape (USFS 2009).*

Biomass. Woody biomass is Wisconsin's most-used renewable energy resource, but the Central Lake Michigan Coastal Ecological Landscape produces only 24.6 million oven-dry tons of biomass, or 2.5% of total statewide production (USFS 2009). There is not great potential for woody biomass from the forests in this ecological landscape.

Hydroelectric. There are six hydroelectric power sites in Outagamie and Brown counties that generate 123 million kilowatt hours (kWh) (WDOA 2006). In the entire state, there are 68 sites, owned either by utility companies or privately owned, which generate a total of 1,462 million kilowatt hours.

Ethanol. The Central Lake Michigan Coastal counties produced 38.9 million bushels of corn in 2002, or 6.6% of total production in the state (USDA NASS 2004). Expanding urbanization is further reducing the acreage of farmland in this region. There are no ethanol plants located in the Central Lake Michigan Coastal Ecological Landscape (Renewable Fuels Association 2014).

Wind. Three of the 13 commercial wind facilities in the state in 2013 are located in the Central Lake Michigan Coastal Ecological Landscape and produce 40.4 MW (megawatts) of power (WWIC 2014). Mean annual power densities are generally between 500 and 600 W/m^2 (watts per square meter) in this part of the state, indicating that there is excellent potential for wind generation here (USDE 2014).

There is considerable wind energy potential along the Lake Michigan shoreline and offshore in the lake itself with mean annual power densities well over 400 watts per square meter (W/m^2) in many areas (USDE 2014). Offshore wind facility projects in Lake Michigan have been proposed in the past but none have been constructed to date. There are concerns for potential mortality to migrating and wintering birds and other negative environmental effects from offshore wind facilities. There are also socioeconomic concerns related to human health, property values, aesthetics, the intermittent nature of wind as a power source, and other factors.

Current Socioeconomic Conditions

The Central Lake Michigan Coastal counties are variable in their demographic makeup. The Central Lake Michigan Coastal counties have slightly younger, slightly more racially diverse populations than other rural Wisconsin counties, with variable education levels. Population and housing densities are variable among the Central Lake Michigan Coastal counties, but generally higher than statewide averages. The Central Lake Michigan Coastal counties' population growth and housing growth exceed that for the state as a whole, especially in the more urban counties.

Table 8.6. *Acreage of timberland in the Central Lake Michigan Coastal Ecological Landscape by forest type and size class.*

Forest type[a]	Seedling/sapling	Pole-size	Sawtimber	Total
Sugarberry-hackberry-elm-green ash	5,367	27,515	21,797	54,679
Black ash-American elm-red maple	3,458	24,836	19,238	47,531
Sugar maple-beech-yellow birch	890	11,804	20,468	33,162
Elm-ash-locust	8,060	10,909	6,028	24,998
Northern white-cedar	–	15,545	7,226	22,770
Hard maple-American basswood	–	4,341	15,541	19,882
Aspen	5,961	9,464	1,954	17,378
Red maple-lowland	–	3,899	11,088	14,987
White oak-red oak-hickory	–	8,742	4,383	13,125
Red maple-upland	–	–	12,346	12,346
Mixed upland hardwoods	–	2,740	5,804	8,544
Silver maple-American elm	–	671	5,899	6,570
White birch	–	2,966	2,772	5,738
Other pine-hardwood	–	5,495	–	5,495
Tamarack	–	4,484	–	4,484
White spruce	3,191	–	1,284	4,475
Northern red oak	–	–	4,220	4,220
Exotic softwoods and hardwoods				4,200
Nonstocked[b]				4,009
Cherry-ash-yellow-poplar	–	1,049	2,310	3,359
Willow	695	–	2,618	3,314
Eastern hemlock	–	–	3,014	3,014
White oak	–	–	2,707	2,707
Cottonwood-willow	1,786	705	–	2,491
Eastern white pine	–	–	2,225	2,225
Post oak-blackjack oak	–	2,012	–	2,012
White pine-red oak-white ash	–	–	680	680
Red pine	–	212	–	212
Total	**29,409**	**137,389**	**153,599**	**328,606**

Source: U.S. Forest Service Forest Inventory and Analysis (FIA) Mapmaker (USFS 2009).
[a]U.S. Forest Service Forest Inventory and Analysis (FIA) uses a national forest typing system to classify FIA forest types from plot and tree list samples. Because FIA is a national program, some of the national forest types in the above table do not exactly represent forest types that occur in Wisconsin. For example, neither post oak nor blackjack oak occur to any great extent in Wisconsin, but since there is no "black oak forest type" in the FIA system, black oak stands in Wisconsin were placed in the "post oak-blackjack oak" category in this table.
[b]Nonstocked land is less than 16.7% stocked with trees and not categorized as to forest type or size class.

Table 8.7. *Road miles and density, railroad miles and density, number of airports, airport runway miles and density, and number of ports in the Central Lake Michigan Coastal Ecological Landscape.*

	Central Lake Michigan Coastal	State total	% of state total
Total road lengtha (miles)[a]	12,376	185,487	7%
Road density[b]	4.6	3.4	–
Miles of railroads	489	5,232	9%
Railroad density[c]	18.0	9.7	–
Airports	7	128	5%
Miles of runway	6.5	95.7	7%
Runway density[d]	2.4	1.8	–
Total land area (excluding water) (mi^2)	2,715	54,087	5%
Number of ports[e]	4	14	29%

[a]Includes primary and secondary highways, roads, and urban streets.
[b]Miles of road per square mile of land. Data from Wisconsin Roads 2000 TIGER line files (data set) (WDOA 2000).
[c]Miles of railroad per 100 square miles of land. Data from 1:100,000-scale Rails Chain Database (WDOT 1998).
[d]Miles of airport runway per 1,000 square miles of land. Data from Wisconsin Airport Directory 2011–2012 web page (WDOT 2012).
[e]Data from Wisconsin Commercial Ports Association (WCPA 2010).

Demography

Population Distribution

According to 2010 U.S. Census Bureau estimates, the combined population of the Central Lake Michigan Coastal counties was 830,001, or 14.6% of the state's total population (USCB 2012b). Only 29.5% of the population in the Central Lake Michigan Coastal counties can be classified as rural, compared to 31.7% statewide (a number that is skewed by the heavy influence of the Milwaukee area). Green Bay in Brown County (103,913 in 2010) is the largest urban center within the Central Lake Michigan Coastal counties. Four other cities in the Central Lake Michigan Coastal counties have populations over 20,000: Appleton in Outagamie County (72,624 in 2010), Sheboygan in Sheboygan County (49,290), Manitowoc in Manitowoc County (33,743), and De Pere in Brown County (23,829). Brown County (248,007 in 2010) and Outagamie County (176,695 in 2010) together comprise over half of the total population in the Central Lake Michigan Coastal counties. Kewaunee County (20,574), Calumet County (48,971), and Waupaca County (52,410) have the lowest populations among the Central Lake Michigan Coastal counties. Six Central Lake Michigan Coastal counties were classified as "metropolitan" by the U.S. Department of Agriculture Economic Research Service in 2003 (USDA ERS 2012b). Kewaunee (82.4% rural population) and Waupaca (63% rural population) counties are the only Central Lake Michigan Coastal counties with a majority of their population classified as "rural."

Population Density

The population density in 2010 of the Central Lake Michigan Coastal Counties (212 persons per square mile) was twice that of Wisconsin as a whole (105 persons per square mile). Among the Central Lake Michigan Coastal counties, Brown County (468 persons per square mile) had the highest population density, followed by Ozaukee (371), Outagamie (277), and Sheboygan (226) counties (USCB 2012b). Waupaca (70) and Kewaunee (60) counties had the lowest population densities among the Central Lake Michigan Coastal counties.

Population Structure

■ **Age.** Population in the Central Lake Michigan Coastal counties is reflective of the state as a whole but is composed of slightly less people of retirement age and slightly more people aged 25–49 years (37.9% in the Central Lake Michigan Coastal counties compared to 36.9% statewide) (USCB 2009). Approximately 24.4% of the 2010 population in the Central Lake Michigan Coastal counties was under 18 years old, compared to 23.6% statewide, and 13.5% of the population was 65 or older, compared to 13.7% statewide (USCB 2012b). The median age was higher than the statewide figure of 36 years old in six Central Lake Michigan Coastal counties, ranging from 36.8 years in Sheboygan County to 38.9 years in Ozaukee County. However, Brown (median age of 34.2 years), Outagamie (34.4), and Calumet (35.2) counties had median ages below the statewide figure (USCB 2009).

■ **Minorities.** The Central Lake Michigan Coastal counties are less racially diverse than the state as a whole but more diverse than most rural ecological landscape county approximations. Ninety-one percent of the 2010 population in the Central Lake Michigan Coastal counties was white, non-Hispanic, compared to 86.2% statewide (USCB 2012b). The Central Lake Michigan Coastal counties were 4.7% Hispanic/Latino, ranking third among all ecological landscape county approximations and compared to 5.9% statewide.

■ **Education.** Education levels of Central Lake Michigan Coastal counties' residents varied widely among individual counties in the region. According to the 2010 U.S. Census, 90.9% of the Central Lake Michigan Coastal counties' residents 25 or older had graduated from high school, compared to 89.4% statewide (USCB 2012b). Central Lake Michigan Coastal county residents were only slightly lower in terms of higher education attainment (25.0% of the Central Lake Michigan Coastal counties' residents had received at least a bachelor's degree or higher, compared to 25.8% statewide). More urban Central Lake Michigan Coastal counties had significantly higher education attainment levels than other Central Lake Michigan Coastal counties. Ozaukee County (with 95.1% of residents graduated from high school and 43.3% having attained at least a bachelor's degree or higher) was surpassed statewide only by Dane County in terms of education attainment. Outagamie County (92.3% and 25.8%, respectively) and Brown County (90.0% and 25.6%) also had high rates of education attainment for high school and bachelor's degrees or higher. Waupaca County (88.2%) was the only county that was below the statewide average (89.4%) of its population graduating from high school. Kewaunee (13.6%), Waupaca (16.1%), Manitowoc (17.5%), and Sheboygan (20.5%) were below the statewide average (25.8%) for persons with a bachelor's degree or higher.

Population Trends

Over the extended period from 1950 to 2006, the Central Lake Michigan Coastal counties' combined population grew at a faster rate (92% population growth) than did the state's population (62%) (USCB 2009). Ozaukee County's population more than tripled, reflecting the growth of the Milwaukee suburbs. Brown, Calumet, and Outagamie counties each more than doubled their population over the period from 1950 to 2006. Meanwhile, Kewaunee (18.4% growth) and Manitowoc (20.6%) counties experienced much slower relative population growth over the same extended period.

Population growth in the Central Lake Michigan Coastal counties combined outpaced statewide growth in each decade since 1950, though the relative difference has slowed continually since 1980. From 1980 to 1990, population growth in the Central Lake Michigan Coastal counties (6.7% growth, compared to 4% statewide), reached its peak relative to statewide growth (USCB 2009). The period from 1990 to 2000 saw increased growth both in the Central Lake Michigan Coastal counties and statewide (12.5% and 9.6%, respectively), but the gap between the two narrowed. Kewaunee, Manitowoc, and Sheboygan counties experienced relatively slow growth in the past two decades while Calumet, Outagamie, and Brown counties have led the Central Lake Michigan Coastal counties' population growth.

Housing

Housing Density. The Central Lake Michigan Coastal counties' combined housing density in 2010 (91.1 housing units per square mile of land) was nearly twice the state's housing density (48.5 units per square mile) (USCB 2012c). Similar to population density, housing density was highest in Brown County (197.0 units per square mile), followed by Ozaukee (155.6), Outagamie (114.7) and Sheboygan (99.3) counties. Rural Central Lake Michigan Coastal counties Kewaunee (27 units per square mile) and Waupaca (34) had comparatively low housing densities.

Seasonal Homes. Seasonal and recreational homes made up only 1.6% of housing stock in the Central Lake Michigan Coastal counties in 2010, compared to the statewide average of 6.3% (USCB 2012d). Of the Central Lake Michigan Coastal counties, only Waupaca County (8.8%) exceeded the statewide average percentage of seasonal housing.

Housing Growth. Over the last half century, the Central Lake Michigan Coastal counties' housing growth has consistently exceeded statewide averages but by smaller margins than have occurred in terms of population growth. Ozaukee County led all Central Lake Michigan Coastal counties in housing growth until the 1970s, when it was overtaken by Sheboygan County, which continues to be a regional and statewide leader in housing growth (USCB 2009). The rate of growth of housing stocks in Calumet County is among the highest in the state since 1980. Brown County has consistently had some of the fastest housing growth among the Central Lake Michigan Coastal counties.

The Central Lake Michigan Coastal counties' housing growth from 1950 to 1960 (41.2%) was only slightly ahead of the statewide average (40.4%) (USCB 2009). Housing growth in the Central Lake Michigan Coastal counties continued to surpass statewide averages by ever-increasing margins. Only Manitowoc County has lagged behind the state in every decade in that period. From 1990 to 2000, Sheboygan County (37.2%) had by far the greatest housing growth among the Central Lake Michigan Coastal counties, and Manitowoc County (15.4%) had the slowest growth, compared to 20.2% housing growth statewide. Sheboygan County's rapid rate of housing development continued from 2000 to 2007 (36.7% was the highest among counties statewide), compared to only 10.3% statewide.

Housing Values. Ozaukee County ($255,600) had the highest median housing value in 2010 in the state (USCB 2012b). Other Central Lake Michigan Coastal counties had values closer to the statewide median housing value ($169,000), ranging from $159,100 in Brown County to the lowest Central Lake Michigan Coastal counties' value in Manitowoc County ($124,000).

The Economy

The Central Lake Michigan Coastal counties make up a large portion of Wisconsin's economic output, where it is especially concentrated in energy and manufacturing. Per capita income and median household income figures are high in the Central Lake Michigan Coastal counties, and wages per job compare favorably with much of the state, indicating an abundance of good paying jobs. Unemployment is low in most Central Lake Michigan Coastal counties, and poverty rates are very low in the Central Lake Michigan Coastal counties. Property values are highly variable among the Central Lake Michigan Coastal counties and are among the state's highest in suburban counties and relatively low in counties less influenced by urban centers.

Income

Per Capita Income. Total personal income for the Central Lake Michigan Coastal counties in 2006 was $29.6 billion (15.4% of the state total). Brown County ($8.35 billion) is the leading contributor, followed by Outagamie ($5.92 billion), Ozaukee ($4.84 billion) and Sheboygan ($4.04 billion) counties (USDC BEA 2006). Combined per capita income in the Central Lake Michigan Coastal counties in 2006 ($36,555) was higher than the statewide average of $34,405. Ozaukee County ($56,816) had the highest per capita income in the state, and four other Central Lake Michigan Coastal counties exceeded the state average. Three Central Lake Michigan Coastal counties have per capita incomes below the statewide average (Table 8.8).

Household Income. Household income in the Central Lake Michigan Coastal counties is relatively high, according to U.S. Census Bureau estimates (USCB 2012b). Six Central Lake Michigan Coastal counties have relatively high median household incomes, led by Ozaukee County ($75,457). Median household income in the Central Lake Michigan Coastal counties in 2013 was less than the statewide median ($52,413) in Waupaca ($50,822) and Manitowoc ($48,881) counties.

Earnings Per Job. In contrast to per capita and household income, the Central Lake Michigan Coastal counties had lower average earnings per job ($35,826) than the statewide average ($36,142), but the Central Lake Michigan Coastal counties ranked behind only the Southern Lake Michigan Coastal counties (Milwaukee area) and the Southeast Glacial Plains counties (Madison and western Milwaukee suburbs) (USDC BEA 2006). Ozaukee County ($39,326) had the third highest earnings per job in the state. Brown County ($37,133) was the only other Central Lake Michigan Coastal County with earnings per job higher than the statewide average (Table 8.8). The lowest earnings per job in the Central Lake Michigan Coastal counties occurred in Calumet ($27,962) and Waupaca ($29,833) counties.

Unemployment

The Central Lake Michigan Coastal counties had a combined 2006 unemployment rate of 4.4%, comparatively lower than the state average of 4.7% (Table 8.8). Ozaukee County (3.6%) had the second lowest unemployment rate among Wisconsin counties. Among the Central Lake Michigan Coastal counties, only Manitowoc (4.9%) and Waupaca (5.0%) had marginally higher unemployment rates than the state as a whole. Unemployment rates became much higher throughout the state after 2008 but have become lower again.

Poverty

■ **Poverty Rates.** The U.S. Census Bureau estimated the Central Lake Michigan Coastal counties' combined 2005 poverty rate for all people at 6.9%, compared to 10.2% for the state as a whole (USCB 2009). Ozaukee County (3.4%) had the state's lowest poverty rate, and the Central Lake Michigan Coastal counties had six of the lowest poverty rates among all Wisconsin counties. Among the Central Lake Michigan Coastal counties, only Brown County (9.3%) had poverty rates approaching statewide levels.

■ **Child Poverty Rates.** Compared to the statewide average (14%), 2005 estimates of poverty rates for people under age 18 in the Central Lake Michigan Coastal counties followed similar trends as with overall poverty rates (USCB 2009). Ozaukee County (3.5%) had the lowest 2005 child poverty rate in the state. Child poverty rates were highest in Brown County (12.3%) but still ranked in the better half of the state's counties. The remaining Central Lake Michigan Coastal counties had child poverty rates ranging from 5.8% in Calumet County to 10.1% in Manitowoc County.

Residential Property Values

Average residential property value in 2006 in the combined Central Lake Michigan Coastal counties ($130,480 per housing unit) was slightly lower than the statewide average ($134,021; Table 8.9). However, residential property values were highly variable between the Central Lake Michigan Coastal counties. Ozaukee County ($246,255) had by far the highest value per residential property among the Central Lake Michigan Coastal counties. Residential Property values in Calumet ($131,626) and Sheboygan ($125,001) counties were just below statewide levels, while the remaining Central Lake Michigan Coastal counties had relatively low values. The Central Lake Michigan Coastal counties' disparate residential property values reflect the correlation between close proximity to large urban centers and higher property values, and their relative lack of recreational property and its associated higher value.

Important Economic Sectors

The Central Lake Michigan Coastal counties together provided an estimated 540,243 jobs in 2007 (Table 8.10; MIG 2009), or about 15.2% of the total employment in Wisconsin. The Manufacturing (non-wood) sector is the principal employer in the Central Lake Michigan Coastal counties (14.5% of their total employment), historically providing steady, well-paying jobs. Tourism-related (11.1%), Government (9.5%), Retail Trade (9.1%), and Health Care and Social Services (9.1%) are other sectors with considerable employment in the Central Lake Michigan Coastal counties. For definitions of economic sectors, see the U.S. Census Bureau's North American Industry Classification System web page (USCB 2013).

The importance of economic sectors within the Central Lake Michigan Coastal counties when compared to the rest of the state was evaluated using an economic base analysis to yield a standard metric called a location quotient (Quintero 2007). Economic base analysis compares the percentage of all jobs in an ecological landscape county approximation for

Table 8.8. *Economic indicators for the Central Lake Michigan Coastal (CLMC) counties and Wisconsin.*

	Per capita income[a]	Average earnings per job[a]	Unemployment rate[b]	Poverty rate[c]
Wisconsin	**$34,405**	**$36,142**	**4.7%**	**10.2%**
Brown	$34,718	$37,133	4.5%	9.3%
Calumet	$36,107	$27,962	4.1%	4.8%
Kewaunee	$30,719	$34,819	4.4%	6.4%
Manitowoc	$31,624	$33,302	4.9%	8.3%
Outagamie	$34,446	$35,958	4.6%	6.3%
Ozaukee	$56,816	$39,326	3.6%	3.4%
Sheboygan	$35,419	$35,618	4.0%	6.2%
Waupaca	$31,662	$29,833	5.0%	7.9%
CLMC counties	**$36,555**	**$35,826**	**4.4%**	**6.9%**

[a]U.S. Bureau of Economic Analysis, 2006 figures.
[b]U.S. Bureau of Labor Statistics, Local Area Unemployment Statistics, 2006 figures.
[c]U.S. Bureau of the Census, Small Area Income and Poverty Estimates, 2005 figures.

Table 8.9. *Property values for the Central Lake Michigan Coastal counties and Wisconsin, assessed in 2006 and collected in 2007.*

	Residential property value	Housing units	Residential property value per housing unit
Wisconsin	**$340,217,559,700**	**2,538,538**	**$134,021**
Brown	$12,102,901,300	101,347	$119,420
Calumet	$2,484,051,200	18,872	$131,626
Kewaunee	$989,268,200	9,040	$109,432
Manitowoc	$3,591,192,800	36,717	$97,807
Outagamie	$8,402,643,200	70,739	$118,784
Ozaukee	$8,716,442,700	35,396	$246,255
Sheboygan	$6,205,058,400	49,640	$125,001
Waupaca	$2,651,381,700	24,224	$109,453
CLMC counties	**$45,142,939,500**	**345,975**	**$130,480**

Sources: Wisconsin Department of Revenue 2006–2007 property tax master file (except housing units); housing units: U. S. Census Bureau estimates for July 1, 2006.

Table 8.10. *Total and percentage of jobs in 2007 in each economic sector within the Central Lake Michigan Coastal (CLMC) counties. The economic sectors providing the highest percentage of jobs in the Central Lake Michigan Coastal Counties are highlighted in blue.*

Industry sector	WI employment	% of WI total	CLMC counties employment	% of CLMC counties total
Agriculture, Fishing & Hunting	110,408	3.1%	14,543	2.7%
Forest Products & Processing	88,089	2.5%	21,972	4.1%
Mining	3,780	0.1%	619	0.1%
Utilities	11,182	0.3%	4,147	0.8%
Construction	200,794	5.6%	34,317	6.4%
Manufacturing (non-wood)	417,139	11.7%	78,273	14.5%
Wholesale Trade	131,751	3.7%	19,732	3.7%
Retail Trade	320,954	9.0%	49,332	9.1%
Tourism-related	399,054	11.2%	60,093	11.1%
Transportation & Warehousing	108,919	3.1%	15,702	2.9%
Information	57,081	1.6%	6,572	1.2%
Finance & Insurance	168,412	4.7%	31,222	5.8%
Real Estate, Rental & Leasing	106,215	3.0%	13,541	2.5%
Professional, Science & Tech Services	166,353	4.7%	21,492	4.0%
Management	43,009	1.2%	5,259	1.0%
Administrative and Support Services	166,405	4.7%	25,051	4.6%
Private Education	57,373	1.6%	7,478	1.4%
Health Care & Social Services	379,538	10.7%	48,965	9.1%
Other Services	187,939	5.3%	30,712	5.7%
Government	430,767	12.1%	51,221	9.5%
Totals	**3,555,161**		**540,243**	**15.2%**

Source: IMPLAN, © MIG, Inc. 2009 (MIG 2009).

a given economic sector to the percentage of all jobs in the state for the same economic sector. For example, if 10% of the jobs within an ecological landscape county approximation are in the manufacturing sector and 10% of all jobs in the state are in the manufacturing sector, then the quotient would be 1.0, indicating that this ecological landscape county approximation contributes jobs to the manufacturing sector at the same rate as the statewide average. If the quotient is greater than 1.0, the ecological landscape county approximation is contributing more jobs to the sector than the state average. If the quotient is less than 1.0, the ecological landscape county approximation is contributing fewer jobs to the sector than the state average.

When compared with the rest of the state, the Central Lake Michigan Coastal counties had eight sectors of employment with quotients higher than 1.0 (Figure 8.21, Appendix 8.I). In part because the Central Lake Michigan Coastal counties make up a significant portion of all employment, only five sectors have quotients exceeding 1.0 by more than 10%. The Central Lake Michigan Coastal counties had the state's highest quotient for the Utilities sector; although it is a minor employer in terms of Central Lake Michigan Coastal counties' jobs, 37% of the state's jobs in the Utilities sector are in the Central Lake Michigan Coastal counties. Roughly a quarter of all primary and secondary Forest Products and Processing (concentrated in secondary products and processing) jobs in the state are based in the Central Lake Michigan Coastal counties. Other sectors with relatively high location quotients, in order of their relative importance, are Manufacturing (nonwood), Finance and Insurance, and Construction. Other sectors providing a percentage of jobs in the Central Lake Michigan Coastal counties only slightly higher than the state average are Mining, Other Services, and Retail trade.

The Other Services sector consists primarily of equipment and machinery repairing, promoting or administering religious activities, grant making, advocacy, and providing drycleaning and laundry services, personal care services, death care services, pet care services, photo finishing services, and parking services. The Tourism-related sector includes relevant subsectors within Retail Trade; Passenger Transportation; Arts, Entertainment and Recreation; and Accommodation and Food Services. The Tourism-related sector is not a separate economic sector as with other industrial classifications and is not easy to separate and identify. Businesses that service tourists also service local demands; however, they are the sectors most sensitive to tourism demands (Marcouiller and Xia 2008). The Forest Products and Processing sector includes sectors in logging, pulp and paper manufacturing, primary wood manufacturing (e.g., sawmills), and secondary wood manufacturing (e.g., furniture manufacturing).

Urban Influence

The U.S. Department of Agriculture's Economic Research Service (USDA ERS) divides counties into 12 groups on a continuum of urban influence, with 1 representing large metropolitan areas, 2 representing smaller metropolitan areas, and the remaining classes from 3 to 12 representing nonmetropolitan (rural) counties increasingly less populated and isolated from urban influence (USDA ERS 2012b). The concept of urban influence assumes population size, urbanization, and access to larger adjacent economies are crucial elements in evaluating potential of local economies. Ozaukee County is categorized as a class 1 county, included in the large metropolitan area of neighboring Milwaukee. Brown, Calumet, Kewaunee, and Sheboygan counties are classified as smaller metro areas (class 2). The remaining Central Lake Michigan Coastal counties are composed of nonmetropolitan (rural) counties with moderate degrees of "influence" from adjacent urban areas. Manitowoc is a class 5 county, while Waupaca is a class 6 county.

Economic Types

Based on the assumption that knowledge and understanding of different types of rural economies and their distinctive economic and sociodemographic profiles can aid rural policymaking, the USDA's Economic Research Service classifies counties in one of six mutually exclusive categories: farming-dependent counties, mining-dependent counties, manufacturing-dependent counties, government-dependent counties, service-dependent counties, and nonspecialized counties (USDA ERS 2012a). Brown County is classified as

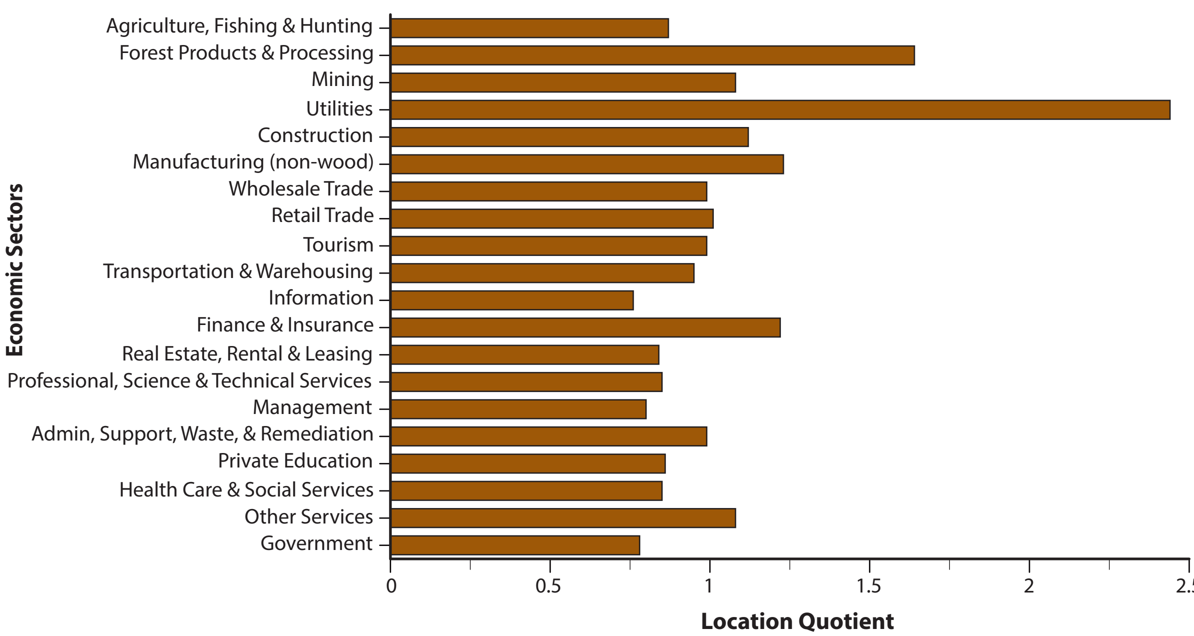


Figure 8.21. *Importance of economic sectors within the Central Lake Michigan Coastal counties when compared to the rest of the state. If the location quotient is greater than 1.0, the Central Lake Michigan Coastal counties are contributing more jobs to that economic sector than the state average. If the location quotient is less than 1.0, the Central Lake Michigan Coastal counties are contributing fewer jobs to that economic sector than the state average.*

nonspecialized. The remaining seven Central Lake Michigan Coastal counties are all classified as manufacturing-dependent, according to USDA ERS specialization definitions.

Policy Types

The USDA Economic Research Service also classifies counties according to "policy types" deemed especially relevant to rural development policy (USDA ERS 2012a). Waupaca County, classified as a "retirement destination" county (those in which the number of residents 60 and older grew by 15% or more between 1990 and 2000 due to in-migration), is shaped by an influx of an older population and has particular needs for health care and services specific to that population.

Integrated Opportunities for Management

Use of natural resources for human needs within the constraints of sustainable ecosystems is an integral part of ecosystem management. Integrating ecological management with socioeconomic programs or activities can result in efficiencies in land use, tax revenues, and private capital. This type of integration can also help generate broader and deeper support for sustainable ecosystem management. However, human modification or use of natural communities has trade-offs that benefit some species and ecosystems and harm others. Even relatively benign activities such as ecotourism will have impacts on the ecology of an area. Trade-offs caused by management actions need to be carefully weighed when planning management to ensure that some species are not being irreparably harmed. Maintaining healthy, sustainable ecosystems provides many benefits to people and our economy. The development of ecologically sound management plans should save money and sustain natural resources in the long run.

The principles of integrating natural resources and socioeconomic activities are similar across the state. See the "Integrated Ecological and Socioeconomic Opportunities" section of Chapter 6, "Wisconsin's Ecological Features and Opportunities for Management." That section offers suggestions on how and when ecological and socioeconomic needs might be integrated and gives examples of the types of activities that might work together when planning the management of natural resources for a given area.

Appendices

Appendix 8.A. *Watershed water quality summary for the Central Lake Michigan Coastal Ecological Landscape.*

Watershed no.	Watershed name	Area (acres)	Overall water quality and major stressors[a] (Range = Very Poor/Poor/Fair/Good/Very Good/Excellent)
GB01	Suamico & Little Suamico River	109,938	Good; nonpoint urban & agr nutrients are increasing
LF01	East River	132,047	Very Good to Poor; NPS controls; lack of streambank cover; erosion & turbidity; PCBs, Hg; wildlife impacts
LF02	Apple and Ashwaubenon creeks	72,539	Fair to Poor; NPS & PS; agr sediment & phosphorus
LF03	Plum and Kankapot creeks	53,786	Fair to Poor; NPS & PS; agr sediment & barnyard runoff
LF04	Fox River - Appleton	25,200	Excessive storm water & erosion; headwaters urbanized
LF05	Duck Creek	97,030	Fair to Poor; urban & agr NPS; sedimentation
MA01	Sevenmile and Silver creeks	72,255	Very Poor to Fair; low flows; low D.O.; high nutrients
MA02	Lower Manitowoc River	107,732	Fair to Good; tribs Fair to Poor; loss of forest/infiltration
MA03	Branch River	69,433	ERW; loss of forest & vegetated buffer; flashy flows
MA04	North Branch Manitowoc River	49,263	Fair; loss of forest, buffers & wetlands; NPS nutrients
MA05	South Branch Manitowoc River	121,022	Poor to Very Good; loss of forest, buffers & wetlands
MI02	Milwaukee River South	107,456	Fair to Poor (303d); NPS nutrients, sediments; PS inputs
SH01	Sauk and Sucker creeks	37,397	Fair to Poor; loss of forest & buffer; flashy flows; NPS
SH02	Black River	22,728	Poor; loss of forest & buffer; flashy flows; NPS
SH03	Sheboygan River	166,477	Headwaters Good; Fair to Poor in lower reaches, with PCB contamination
SH04	Onion River	62,717	Headwaters Good to Excellent; Fair to Poor in lower reaches; loss of forest & buffer; flashy flows; NPS
SH05	Mullet River	56,442	Headwaters Good; Good to Fair lower; NPS
SH06	Pigeon River	50,474	Headwaters Good; Fair to Poor lower; NPS
TK01	West Twin River	115,266	Good; NPS nutrients; PCBs; decreased infiltration
TK02	East Twin River	117,493	Fair to Good; PCBs; NPS sediment & nutrients; dam
TK03	Kewaunee River	90.956	Fair to Good; point & nonpoint inputs
TK04	Ahnapee River	86,773	Fair to Good; excess nutrients & PCBs, lack of buffers
TK07	Red River and Sturgeon Bay	19,229	Excess agr nutrients, low D.O.; loss of forest/infiltration
WR01	Arrowhead River and Daggets Crks	91,463	Fair to Good; low D.O.; NPS from barnyard runoff
WR04	Lower Wolf River	76,768	Good; Hg in fish samples
WR06	Lower Little Wolf River	98,307	Fair to Good; animal waste and soil erosion problems
WR08	South Branch Little Wolf River	102,586	Good: sediments and habitat deterioration from streambank pasturing
WR10	Pigeon River	74,444	Fair to Good; excess vegetation, turbidity, and habitat degradation.
WR11	Middle & S. Branch Embarrass River	160,004	Good; animal waste and soil erosion problems
WR12	Wolf R. New London and Bear Crk	91,191	Good; but Fair in tribs with poultry and feed lot wastes
WR13	Shioc River	121,447	Good to Fair; flow flux; lacking cropland buffers
WR14	Middle Wolf River	85,619	Good; some NPS animal waste and cropland runoff

Source: Wisconsin DNR Bureau of Watershed Management data.
[a]Based on Wisconsin DNR watershed water quality reports.

Abbreviations:
Agr = Agricultural.
D.O. = Dissolved oxygen.
ERW = Exceptional Resource Water (very good to excellent water quality, with point source discharges).
Flux = Abnormal fluctuations in stream flow due to lack of groundwater infiltration caused by loss of forest cover or creation of excessive impermeable surfaces.
Hg = Mercury contamination of fish, mainly deposited by coal combustion, or sometimes by industry.
NPS = Nonpoint source pollutants, such as farm field and parking lot runoff.
PCBs = Polychlorinated biphenyl industrial pollutants in sediment and aquatic life.
PS = Point source pollutants, such as treated municipal and industrial wastewater.
Tribs = Streams that are tributary to the stream(s) after which the watershed is named.
303(d) = A water listed as impaired under Section 303(d) of the federal Clean Water Act.

Appendix 8.B. *Forest habitat types in the Central Lake Michigan Coastal Ecological Landscape.*

The forest habitat type classification system (FHTCS) is a site classification system based on the floristic composition of plant communities. The system depends on the identification of potential climax associations, repeatable patterns in the composition of the understory vegetation, and differential understory species. It groups land units with similar capacity to produce vegetation. The floristic composition of the plant community is used as an integrated indicator of those environmental factors that affect species reproduction, growth, competition, and community development. This classification system enables the recognition and classification of ecologically similar ecological landscape units (site types) and forest plant communities (vegetation associations).

A forest habitat type is an aggregation of sites (units of land) capable of producing similar late-successional (potential climax) forest plant communities. Each recognizable habitat type represents a relatively narrow segment of environmental variation that is characterized by a certain limited potential for vegetation development. Although at any given time, a habitat type can support a variety of disturbance-induced (seral) plant communities, the ultimate product of succession is presumed to be a similar climax community. Field identification of a habitat type provides a convenient label (habitat type name) for a given site, and places that site in the context of a larger group of sites that share similar ecological traits. Forest habitat type groups more broadly combine individual habitat types that have similar ecological potentials.

Individual forest cover types classify current overstory vegetation, but these associations usually encompass a wide range of environmental conditions. In contrast, individual habitat types group ecologically similar sites in terms of vegetation potentials. Management interpretations can be refined and made significantly more accurate by evaluating a stand in terms of the current cover type (current dominant vegetation) plus the habitat type (potential vegetation).

Habitat types	Description of forest habitat types found in the Central Lake Michigan Coastal Ecological Landscape.
ATFD	*Acer saccharum-Tsuga canadensis-Fagus grandifolia/Dryopteris spinulosa* Sugar maple-Eastern hemlock-American beech/Spinulose shield fern
AFH	*Acer saccharum-Fagus grandifolia/Hydrophyllum virginianum* Sugar maple-American beech/Virginia waterleaf
AFAs	*Acer saccharum-Fagus grandifolia/Arisaema* Sugar maple-American beech/Jack-in-the-pulpit
AFH	*Acer saccharum-Fagus grandifolia/Arisaema*, *Osmorhiza* variant Sugar maple-American beech/Jack-in-the-pulpit, Sweet cicely variant
AH	*Acer saccharum/Hydrophyllum virginianum* Sugar maple/Virginia waterleaf

Source: Kotar and Burger (1996).

Appendix 8.C. *The Natural Heritage Inventory (NHI) table of rare species and natural community occurrences (plus a few miscellaneous features tracked by the NHI program) for the Central Lake Michigan Coastal (CLMC) Ecological Landscape in November 2009. See the Wisconsin Natural Heritage Working List online for the current status (*http://dnr.wi.gov*, keyword "NHI").*

Scientific name (common name)	Lastobs Date	EOs[a] in CLMC	EOs in WI	Percent in CLMC	State rank	Global rank	State status	Federal status
MAMMALS								
Myotis septentrionalis (northern long-eared bat)[b]	1980	2	9	22%	S3	G4	SC/N	
Sorex hoyi (pygmy shrew)	1987	1	39	3%	S3S4	G5	SC/N	
BIRDS[c]								
Accipiter gentilis (Northern Goshawk)	1999	1	141	1%	S2B,S2N	G5	SC/M	
Ammodramus henslowii (Henslow's Sparrow)	2000	5	82	6%	S3B	G4	THR	
Anas acuta (Northern Pintail)	1995	1	1	100%	S1B	G5	SC/M	
Ardea alba (Great Egret)	2001	1	14	7%	S2B	G5	THR	
Aythya americana (Redhead)	1995	1	1	100%	S2B	G5	SC/M	
Bartramia longicauda (Upland Sandpiper)	2001	12	54	22%	S2B	G5	SC/M	
Botaurus lentiginosus (American Bittern)	2009	4	41	10%	S3B	G4	SC/M	
Bubulcus ibis (Cattle Egret)	1996	1	3	33%	S1B	G5	SC/M	
Buteo lineatus (Red-shouldered Hawk)	2008	16	301	5%	S3S4B,S1N	G5	THR	
Chlidonias niger (Black Tern)	2009	7	60	12%	S2B	G4	SC/M	
Coturnicops noveboracensis (Yellow Rail)	1991	1	22	5%	S1B	G4	THR	
Dendroica caerulescens (Black-throated Blue Warbler)[d]	2006	1	27	4%	S3B	G5	SC/M	
Dendroica cerulea (Cerulean Warbler)[d]	2000	7	92	8%	S2S3B	G4	THR	
Egretta thula (Snowy Egret)	1996	1	1	100%	S1B	G5	END	
Empidonax virescens (Acadian Flycatcher)	2001	1	47	2%	S3B	G5	THR	
Falco peregrinus (Peregrine Falcon)	2009	6	23	26%	S1S2B	G4	END	
Gallinula chloropus (Common Moorhen)	2001	3	10	30%	S2B	G5	SC/M	
Haliaeetus leucocephalus (Bald Eagle)	2008	30	1286	2%	S4B,S2N	G5	SC/P	
Ixobrychus exilis (Least Bittern)	2000	6	23	26%	S3B	G5	SC/M	
Lanius ludovicianus (Loggerhead Shrike)	1999	2	31	6%	S1B	G4	END	
Nycticorax nycticorax (Black-crowned Night-heron)	2009	7	36	19%	S2B	G5	SC/M	
Pandion haliaetus (Osprey)	2008	44	733	6%	S4B	G5	SC/M	
Pelecanus erythrorhynchos (American White Pelican)	2001	1	2	50%	S1B,S1N	G3	SC/M	
Phalaropus tricolor (Wilson's Phalarope)	1999	1	4	25%	S1B	G5	SC/M	
Protonotaria citrea (Prothonotary Warbler)	2000	10	40	25%	S3B	G5	SC/M	
Rallus elegans (King Rail)	2000	2	6	33%	S1B	G4	SC/M	
Spiza americana (Dickcissel)	1999	9	46	20%	S3B	G5	SC/M	
Sterna caspia (Caspian Tern)[d]	1997	2	7	29%	S1B,S2N	G5	END	
Sterna forsteri (Forster's Tern)	1998	6	31	19%	S1B	G5	END	
Sterna hirundo (Common Tern)	1997	3	14	21%	S1B,S2N	G5	END	
Sturnella neglecta (Western Meadowlark)	2001	8	39	21%	S2B	G5	SC/M	
Tyto alba (Barn Owl)	1982	4	29	14%	S1B,S1N	G5	END	
Wilsonia canadensis (Canada Warbler)[d]	2007	3	20	15%	S3B	G5	SC/M	
Wilsonia citrina (Hooded Warbler)[d]	2006	1	32	3%	S2S3B	G5	THR	
HERPTILES								
Acris crepitans (northern cricket frog)	1983	6	102	6%	S1	G5	END	
Diadophis punctatus edwardsii (northern ring-necked snake)	1998	2	23	9%	S3?	G5T5	SC/H	
Emydoidea blandingii (Blanding's turtle)	2007	14	316	4%	S3	G4	THR	
Glyptemys insculpta (wood turtle)	2006	15	262	6%	S2	G4	THR	
Hemidactylium scutatum (four-toed salamander)	1995	1	63	2%	S3	G5	SC/H	

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Appendix 8.C, *continued.*

Scientific name (common name)	Lastobs date	EOs[a] in in CLMC	EOs in WI	Percent in CLMC	State rank	Global rank	State status	Federal status
Lithobates catesbeianus (American bullfrog)	2001	2	70	3%	S3	G5	SC/H	
Thamnophis butleri (Butler's gartersnake)	2008	4	114	4%	S3	G4	THR	
FISHES								
Acipenser fulvescens (lake sturgeon)	2005	36	99	36%	S3	G3G4	SC/H	
Anguilla rostrata (American eel)	1974	2	24	8%	S2	G4	SC/N	
Clinostomus elongatus (redside dace)	1994	5	96	5%	S3	G3G4	SC/N	
Erimyzon sucetta (lake chubsucker)	1976	1	85	1%	S3	G5	SC/N	
Etheostoma clarum (western sand darter)	1994	2	11	18%	S3	G3	SC/N	
Lepomis megalotis (longear sunfish)	1973	2	25	8%	S2	G5	THR	
Luxilus chrysocephalus (striped shiner)	1979	3	10	30%	S1	G5	END	
Lythrurus umbratilis (redfin shiner)	2007	2	37	5%	S2	G5	THR	
Moxostoma carinatum (river redhorse)	1981	1	43	2%	S2	G4	THR	
Moxostoma valenciennesi (greater redhorse)	1996	10	56	18%	S3	G4	THR	
Notropis texanus (weed shiner)	1995	3	45	7%	S3	G5	SC/N	
Opsopoeodus emiliae (pugnose minnow)	1973	1	31	3%	S3	G5	SC/N	
MUSSELS/CLAMS								
Alasmidonta marginata (elktoe)	1996	4	44	9%	S4	G4	SC/P	
Alasmidonta viridis (slippershell mussel)	1997	2	16	13%	S2	G4G5	THR	
Epioblasma triquetra (snuffbox)[e]	1995	2	5	40%	S1	G3	END	
Pleurobema sintoxia (round pigtoe)	1995	1	50	2%	S3	G4G5	SC/P	
Quadrula metanevra (monkeyface)	1996	1	11	9%	S2	G4	THR	
Simpsonaias ambigua (salamander mussel)	1989	6	51	12%	S2S3	G3	THR	
Tritogonia verrucosa (buckhorn)	2005	1	12	8%	S2	G4G5	THR	
Venustaconcha ellipsiformis (ellipse)	1997	3	28	11%	S2	G4	THR	
MISCELLANEOUS INVERTEBRATES								
Catinella gelida (a land snail)	1998	3	15	20%	S1S2	G1	SC/N	
Glyphyalinia rhoadsi (sculpted glyph)	1996	2	6	33%	S2	G5	SC/N	
Guppya sterkii (brilliant granule)	1997	2	3	67%	S2S3	G5	SC/N	
Hendersonia occulta (cherrystone drop)	1998	20	53	38%	S3	G4	THR	
Paravitrea multidentata (dentate supercoil)	1998	10	39	26%	S2S3	G5	SC/N	
Pupoides albilabris (white-lip dagger)	1995	1	1	100%	S3	G5	SC/N	
Striatura ferrea (black striate)	1998	2	14	14%	S2	G5	SC/N	
Strobilops affinis (eightfold pinecone)	1998	5	7	71%	S3	G4G5	SC/N	
Vallonia excentrica (oval vallonia)	1996	1	1	100%	S3	G5	SC/N	
Vertigo elatior (tapered vertigo)	1998	5	12	42%	S3	G5	SC/N	
Vertigo hubrichti (Midwest Pleistocene vertigo)	1997	10	47	21%	S1	G3	END	
Vertigo nylanderi (deep-throated vertigo)	1998	1	2	50%	S1	G3G4	SC/N	
Vertigo sp. 2 (Iowa Pleistocene vertigo)	1997	4	21	19%	S1S2	G3Q	SC/N	
Vertigo tridentata (honey vertigo)	1996	1	7	14%	S3	G5	SC/N	
Vitrina angelicae (transparent vitrine snail)	2002	1	4	25%	S1	G5	SC/N	
BUTTERFLIES/MOTHS								
Callophrys henrici (Henry's elfin)	1990	1	19	5%	S1S2	G5	SC/N	
Chlosyne gorgone (gorgone checker spot)	1991	2	40	5%	S3	G5	SC/N	
Copablepharon michiganensis (a noctuid moth)	1992	1	1	100%	S1	G1G2	SC/N	
Erynnis lucilius (columbine dusky wing)	1991	1	11	9%	S2	G4	SC/N	
Erynnis martialis (mottled dusky wing)	1985	2	10	20%	S2	G3	SC/N	

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Appendix 8.C, *continued.*

Scientific name (common name)	Lastobs date	EOs[a] in in CLMC	EOs in WI	Percent in CLMC	State rank	Global rank	State status	Federal status
Euphyes bimacula (two-spotted skipper)	1989	3	17	18%	S3	G4	SC/N	
Grammia phyllira (Phyllira tiger moth)	1992	2	14	14%	S2	G4	SC/N	
Hesperia leonardus (Leonard's skipper)	2000	1	29	3%	S3	G4	SC/N	
Lycaeides melissa samuelis (Karner blue)	1993	1	316	0%	S3	G5T2	SC/FL	LE
Macrochilo bivittata (an owlet moth)	1994	1	8	13%	S3	G3G4	SC/N	
Phyciodes batesii lakota (Lakota crescent)	1991	1	24	4%	S3	G4T4	SC/N	
Poanes massasoit (mulberry wing)	2000	7	56	13%	S3	G4	SC/N	
Poanes viator (broad-winged skipper)	2000	11	36	31%	S3	G5	SC/N	
Pompeius verna (little glassy wing)	1991	1	7	14%	S1?	G5	SC/N	
DRAGONFLIES/DAMSELFLIES								
Hetaerina titia (dark rubyspot)	1999	1	4	25%	S1S2	G5	SC/N	
Ophiogomphus howei (pygmy snaketail)	1999	4	33	12%	S4	G3	THR	
Somatochlora hineana (Hine's emerald)	2003	2	15	13%	S1	G2G3	END	LE
BEETLES								
Agabus bicolor (a predaceous diving beetle)	1999	1	9	11%	S3	GNR	SC/N	
Agabus inscriptus (a predaceous diving beetle)	1999	1	1	100%	S2S3	GNR	SC/N	
Agabus wasastjernae (a predaceous diving beetle)	2000	1	1	100%	S2?	GNR	SC/N	
Celina hubbelli (a predaceous diving beetle)	1999	2	2	100%	S2S3	GNR	SC/N	
Cicindela hirticollis rhodensis (beach-dune tiger beetle)	2000	1	8	13%	S2	G5T4	SC/N	
Cicindela lepida (little white tiger beetle)	2000	1	13	8%	S2	G3G4	SC/N	
Cicindela patruela huberi (a tiger beetle)	2000	2	84	2%	S3	G3T3	SC/N	
Cicindela patruela patruela (a tiger beetle)	2000	3	26	12%	S2	G3T3	SC/N	
Cymbiodyta acuminata (a water scavenger beetle)	1999	3	7	43%	S3	GNR	SC/N	
Cymbiodyta minima (a water scavenger beetle)	1999	1	3	33%	S3	GNR	SC/N	
Dubiraphia robusta (robust dubiraphian riffle beetle)	1994	1	2	50%	S1	G1G3	SC/N	
Enochrus consortus (a water scavenger beetle)	2000	5	5	100%	S3	GNR	SC/N	
Enochrus perplexus (a water scavenger beetle)	2000	1	1	100%	S2?	GNR	SC/N	
Enochrus sayi (a water scavenger beetle)	1999	1	1	100%	S3	GNR	SC/N	
Haliplus canadensis (a crawling water beetle)	1999	1	2	50%	S2	GNR	SC/N	
Haliplus pantherinus (a crawling water beetle)	1999	1	13	8%	S2S3	GNR	SC/N	
Hydrochara leechi (a water scavenger beetle)	1999	1	1	100%	S1	GNR	SC/N	
Hydroporus badiellus (a predaceous diving beetle)	1999	1	7	14%	S3?	GNR	SC/N	
Ilybius discedens (a predaceous diving beetle)	1999	1	3	33%	S3	GNR	SC/N	
Laccobius agilis (a water scavenger beetle)	1999	1	4	25%	S2S3	GNR	SC/N	
Liodessus cantralli (Cantrall's bog beetle)	1999	1	4	25%	S1S2	GNR	SC/N	
Lioporeus triangularis (a predaceous diving beetle)	1996	1	4	25%	S1S2	GNR	SC/N	
Matus bicarinatus (a predaceous diving beetle)	2000	3	5	60%	S2S3	GNR	SC/N	
Stenelmis fuscata (a riffle beetle)	1999	4	5	80%	S3	GNR	SC/N	
MISCELLANEOUS INSECTS/SPIDERS								
Aeropedellus clavatus (club-horned grasshopper)	2008	1	3	33%	S2	G5	SC/N	
Hebrus buenoi (a velvet waterbug)	2000	1	1	100%	S1?	G4	SC/N	
Isoperla bilineata (a perlodid stonefly)	1999	1	8	13%	S2S3	G5	SC/N	
Isoperla marlynia (a perlodid stonefly)	1999	1	5	20%	S3	G5	SC/N	
Limotettix elegans (a leafhopper)	1999	1	1	100%	S1?	GNR	SC/N	
Paracloeodes minutus (a small minnow mayfly)	1992	1	4	25%	S1?	G5	SC/N	
Parameletus chelifer (a primitive minnow mayfly)	1993	1	2	50%	S1?	G5	SC/N	
Plauditus cestus (a small minnow mayfly)	1999	1	2	50%	S2	G5	SC/N	

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Appendix 8.C, *continued.*

Scientific name (common name)	Lastobs date	EOs[a] in in CLMC	EOs in WI	Percent in CLMC	State rank	Global rank	State status	Federal status
Pseudiron centralis (a flat-headed mayfly)	1999	2	10	20%	S3	G5	SC/N	
Trachyrhachys kiowa (ash-brown grasshopper)	1999	1	4	25%	S2	G5	SC/N	
Triaenodes nox (a long-horned casemaker caddisfly)	2000	2	2	100%	S1S3	G5	SC/N	
Trimerotropis maritima (seaside grasshopper)	1999	1	3	33%	S2S3	G5	SC/N	
PLANTS								
Adlumia fungosa (climbing fumitory)	2001	4	29	14%	S2	G4	SC	
Aster furcatus (forked aster)	2008	8	44	18%	S3	G3	THR	
Botrychium campestre (prairie dunewort)	1985	1	4	25%	S1	G3G4	END	
Cacalia suaveolens (sweet-scented Indian-plantain)	1996	2	28	7%	S3	G4	SC	
Cakile lacustris (American sea-rocket)	2008	19	40	48%	S3	G5	SC	
Calamagrostis stricta (slim-stem small-reedgrass)	2001	2	34	6%	S3	G5	SC	
Calamovilfa longifolia var. *magna* (sand reedgrass)	2000	6	10	60%	S2	G5T3T5	THR	
Cardamine pratensis (cuckooflower)	2005	4	42	10%	S3	G5	SC	
Carex crawei (crawe sedge)	1999	2	24	8%	S3	G5	SC	
Carex formosa (handsome sedge)	2001	8	16	50%	S2	G4	THR	
Carex richardsonii (Richardson sedge)	1999	2	24	8%	S2	G4	SC	
Carex sychnocephala (many-headed sedge)	2001	1	15	7%	S2	G4	SC	
Cirsium pitcheri (dune thistle)	2008	2	9	22%	S2	G3	THR	LT
Cypripedium parviflorum var. *makasin* (northern yellow lady's-slipper)	2007	12	78	15%	S3	G5T4Q	SC	
Cypripedium reginae (showy lady's-slipper)	2007	5	99	5%	S3	G4	SC	
Cystopteris laurentiana (Laurentian bladder fern)	1978	2	11	18%	S2	G3	SC	
Eleocharis compressa (flat-stemmed spike-rush)	1987	1	9	11%	S2	G4	SC	
Elymus lanceolatus ssp. *psammophilus* (thickspike)	1996	3	12	25%	S2	G5T3	THR	
Equisetum variegatum (variegated horsetail)	2001	4	47	9%	S3	G5	SC	
Erigenia bulbosa (harbinger-of-spring)	2000	1	1	100%	S1	G5	END	
Euphorbia polygonifolia (seaside spurge)	2001	6	20	30%	S2	G5?	SC	
Galium palustre (marsh bedstraw)	1988	1	4	25%	S1	G5	SC	
Gentiana alba (yellow gentian)	2000	7	80	9%	S3	G4	THR	
Gymnocarpium robertianum (limestone oak fern)	1993	1	8	13%	S2	G5	SC	
Iris lacustris (dwarf lake iris)	2005	3	41	7%	S3	G3	THR	LT
Jeffersonia diphylla (twinleaf)	1994	4	23	17%	S3	G5	SC	
Lithospermum latifolium (American gromwell)	2000	7	62	11%	S3	G4	SC	
Medeola virginiana (Indian cucumber-root)	2006	7	42	17%	S3	G5	SC	
Onosmodium molle (marbleseed)	1993	1	42	2%	S3	G4G5	SC	
Orobanche fasciculata (clustered broomrape)	1979	2	2	100%	S1	G4	THR	
Phegopteris hexagonoptera (broad beech fern)	2001	1	17	6%	S2	G5	SC	
Polystichum acrostichoides (Christmas fern)	1995	7	13	54%	S2	G5	SC	
Ptelea trifoliata (wafer-ash)	1978	1	14	7%	S2	G5	SC	
Pterospora andromedea (giant pinedrops)	1979	1	3	33%	S1	G5	END	
Ranunculus cymbalaria (seaside crowfoot)	1990	1	15	7%	S2	G5	THR	
Rhus aromatica (fragrant sumac)	1972	1	5	20%	S1	G5	SC	
Ruellia humilis (hairy wild-petunia)	2004	1	13	8%	S2	G5	END	
Salix cordata (sand dune willow)	2001	1	1	100%	S1	G4	END	
Solidago ohioensis (Ohio goldenrod)	1976	1	74	1%	S3	G4	SC	
Solidago simplex var. *gillmanii* (dune goldenrod)	1978	1	16	6%	S2	G5T3?	THR	
Tofieldia glutinosa (sticky false-asphodel)	1984	1	23	4%	S2S3	G4G5	THR	
Triglochin maritima (common bog arrow-grass)	2001	2	59	3%	S3	G5	SC	
Triglochin palustris (slender bog arrow-grass)	2001	2	36	6%	S3	G5	SC	

Continued on next page

Appendix 8.C, *continued.*

Scientific name (common name)	Lastobs date	EOs[a] in in CLMC	EOs in WI	Percent in CLMC	State rank	Global rank	State status	Federal status
Trillium nivale (snow trillium)	1996	14	34	41%	S3	G4	THR	
Viola rostrata (long-spur violet)	1994	7	22	32%	S2S3	G5	SC	
COMMUNITIES								
Alder Thicket	1978	4	106	4%	S4	G4	NA	
Alvar	1999	1	2	50%	S1	G3	NA	
Black Spruce Swamp	2007	1	41	2%	S3?	G5	NA	
Clay Seepage Bluff	2001	1	1	100%	S2	GNR	NA	
Dry Prairie	1978	1	146	1%	S3	G3	NA	
Emergent Marsh	2007	8	272	3%	S4	G4	NA	
Emergent Marsh - Wild Rice	2000	2	15	13%	S3	G3G4	NA	
Floodplain Forest	2001	13	182	7%	S3	G3?	NA	
Great Lakes Beach	2007	5	24	21%	S2	G3	NA	
Great Lakes Dune	2006	2	15	13%	S2	G3	NA	
Great Lakes Ridge and Swale	2006	3	7	43%	S2	G3	NA	
Hardwood Swamp	2006	7	53	13%	S3	G4	NA	
Interdunal Wetland	2006	2	6	33%	S1	G2?	NA	
Lake—Deep, Hard, Seepage	1985	4	22	18%	S2	GNR	NA	
Lake—Shallow, Hard, Drainage	2001	1	35	3%	SU	GNR	NA	
Lake—Shallow, Hard, Seepage	1982	2	52	4%	SU	GNR	NA	
Lake—Soft Bog	1979	3	52	6%	S4	GNR	NA	
Moist Cliff	1982	5	176	3%	S4	GNR	NA	
Northern Dry Forest	1978	2	63	3%	S3	G3?	NA	
Northern Dry-mesic Forest	2006	14	284	5%	S3	G4	NA	
Northern Mesic Forest	2004	23	383	6%	S4	G4	NA	
Northern Sedge Meadow	2006	11	231	5%	S3	G4	NA	
Northern Wet Forest	1982	6	322	2%	S4	G4	NA	
Northern Wet-mesic Forest	2007	18	243	7%	S3S4	G3?	NA	
Open Bog	2007	4	173	2%	S4	G5	NA	
Sand Prairie	1999	1	28	4%	S2	GNR	NA	
Shrub-carr	2007	3	143	2%	S4	G5	NA	
Southern Dry-mesic Forest	2000	6	293	2%	S3	G4	NA	
Southern Hardwood Swamp	2001	5	30	17%	S2	G4?	NA	
Southern Mesic Forest	2001	6	221	3%	S3	G3?	NA	
Southern Sedge Meadow	2006	3	182	2%	S3	G4?	NA	
Spring Pond	1978	1	69	1%	S3	GNR	NA	
Stream—Fast, Hard, Cold	1981	1	98	1%	S4	GNR	NA	
Stream—Slow, Hard, Warm	1978	1	20	5%	SU	GNR	NA	
Tamarack (Poor) Swamp	1999	1	33	3%	S3	G4	NA	
OTHER ELEMENTS								
Bat hibernaculum	1990	1	43	2%	S3	GNR	SC	
Bird rookery	2004	1	54	2%	SU	G5	SC	
Migratory bird concentration site	1988	1	8	13%	SU	G3	SC	

[a]An element occurrence is an area of land and/or water in which a rare species or natural community is, or was, present. Element occurrences must meet strict criteria that is used by an international network of Heritage programs and coordinated by NatureServe.

[b]Northern long-eared bat (*Myotis septentrionalis*) was listed as Wisconsin Threatened in 2011 and as U.S. Threatened in 2015.

[c]The common names of birds are capitalized in accordance with the checklist of the American Ornithologists Union.

[d]The American Ornithologist's Union lists these birds as Black-throated Blue Warbler (*Setophaga caerulescens*), Hooded Warbler (*Setophaga citrine),* Cerulean Warbler (*Setophaga cerulea*), Canada Warbler (*Cardellina canadensis*), and Caspian Tern (*Hydroprogne caspia)*.

[e]The snuffbox mussel (*Epioblasma triquetra*) was listed as U.S. Endangered in 2012.

Status and ranking definitions on next page

Appendix 8.C, *continued.*

STATUS AND RANKING DEFINITIONS

U.S. Status—Current federal protection status designated by the Office of Endangered Species, U.S. Fish and Wildlife Service, indicating the biological status of a species in Wisconsin:
LE = listed endangered.
LT = listed threatened.
PE = proposed as endangered.
NEP = nonessential experimental population.
C = candidate for future listing.
CH = critical habitat.

State Status—Protection category designated by the Wisconsin DNR:
END = Endangered. Endangered species means any species whose continued existence as a viable component of this state's wild animals or wild plants is determined by the Wisconsin DNR to be in jeopardy on the basis of scientific evidence.
THR = Threatened species means any species of wild animals or wild plants that appears likely, within the foreseeable future, on the basis of scientific evidence to become endangered.
SC = Special Concern. Special Concern species are those species about which some problem of abundance or distribution is suspected but not yet proven. The main purpose of this category is to focus attention on certain species before they become threatened or endangered.

Wisconsin DNR and federal regulations regarding Special Concern species range from full protection to no protection. The current categories and their respective level of protection are as follows:
SC/P = fully protected;
SC/N = no laws regulating use, possession, or harvesting;
SC/H = take regulated by establishment of open closed seasons;
SC/FL = federally protected as endangered or threatened but not so designated by Wisconsin DNR;
SC/M = fully protected by federal and state laws under the Migratory Bird Act.

Global Element Ranks:
G1 = Critically imperiled globally because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2 = Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3 = Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single state or physiographic region) or because of other factor(s) making it vulnerable to extinction throughout its range; typically 21-100 occurrences.
G4 = Uncommon but not rare (although it may be quite rare in parts of its range, especially at the periphery) and usually widespread. Typically > 100 occurrences.
G5 = Common, widespread, and abundant (although it may be quite rare in parts of its range, especially at the periphery). Not vulnerable in most of its range.
GH = Known only from historical occurrence throughout its range, with the expectation that it may be rediscovered.
GNR = Not ranked. Replaced G? rank and some GU ranks.
GU = Currently unrankable due to lack of data or substantially conflicting data on status or trends. Possibly in peril range-wide, but status is uncertain.
GX = Presumed to be extinct throughout its range (e.g., Passenger pigeon) with virtually no likelihood that it will be rediscovered.

Species with a questionable taxonomic assignment are given a "Q" after the global rank. Subspecies and varieties are given subranks composed of the letter "T" plus a number or letter. The definition of the second character of the subrank parallels that of the full global rank. (Examples: a rare subspecies of a rare species is ranked G1T1; a rare subspecies of a common species is ranked G5T1.)

State Element Ranks:
S1 = Critically imperiled in Wisconsin because of extreme rarity, typically 5 or fewer occurrences and/or very few (<1,000) remaining individuals or acres, or due to some factor(s) making it especially vulnerable to extirpation from the state.
S2 = Imperiled in Wisconsin because of rarity, typically 6–20 occurrences and/or few (1,000– 3,000) remaining individuals or acres, or due to some factor(s) making it very vulnerable to extirpation from the state.
S3 = Rare or uncommon in Wisconsin, typically 21–100 occurrences and/or 3,000–10,000 individuals.
S4 = Apparently secure in Wisconsin, usually with > 100 occurrences and > 10,000 individuals.
S5 = Demonstrably secure in Wisconsin and essentially ineradicable under present conditions.
SNA = Accidental, nonnative, reported but unconfirmed, or falsely reported.
SH = Of historical occurrence in Wisconsin, perhaps having not been verified in the past 20 years and suspected to be still extant. Naturally, an element would become SH without such a 20-year delay if the only known occurrence were destroyed or if it had been extensively and unsuccessfully looked for.
SNR = Not Ranked; a state rank has not yet been assessed.
SU = Currently unrankable. Possibly in peril in the state, but status is uncertain due to lack of information or substantially conflicting data on status or trends.
SX = Apparently extirpated from the state.

State ranking of long-distance migrant animals:
Ranking long distance aerial migrant animals presents special problems relating to the fact that their nonbreeding status (rank) may be quite different from their breeding status, if any, in Wisconsin. In other words, the conservation needs of these taxa may vary between seasons. In order to present a less ambiguous picture of a migrant's status, it is necessary to specify whether the rank refers to the breeding (B) or nonbreeding (N) status of the taxon in question. (e.g., S2B, S5N).

Appendix 8.D. *Number of species with special designations documented within the Central Lake Michigan Coastal Ecological Landscape, 2009.*

Listing status[a]	Taxa					Total fauna	Total flora	Total listed
	Mammals	Birds	Herptiles	Fishes	Invertebrates			
U.S. Endangered	0	0	0	0	2	2	0	2
U.S. Threatened	0	0	0	0	0	0	2	2
U.S. Candidate	0	0	0	0	0	0	0	0
Wisconsin Endangered	0	7	1	1	3	12	5	17
Wisconsin Threatened	0	7	3	4	7	21	12	33
Wisconsin Special Concern	2	20	3	7	66	98	28	126
Natural Heritage Inventory total	**2**	**34**	**7**	**12**	**76**	**131**	**45**	**176**

Note: Wisconsin-listed species always include federally listed species (although they may not have the same designation); therefore, federally listed species are not included in the total.

[a]Snuffbox (*Epioblasma triquetra*) mussel was listed as U.S. Endangered in 2012, and the northern long-eared bat (*Myotis septentrionalis*) was listed as Wisconsin Threatened in 2011 and as U.S. Threatened in 2015; these species are not included in the numbers above.

Appendix 8.E. *Species of Greatest Conservation Need (SGCN) found in the Central Lake Michigan Coastal Ecological Landscape.*

These SGCN have a high or moderate probability of being found in this ecological landscape and use habitats that have the best chance for management here. Data are from the Wisconsin Wildlife Action Plan (WDNR 2005b) and Appendix E, "Opportunities for Sustaining Natural Communities in Each Ecological Landscape," in Part 3 of the book, "Supporting Materials." For more complete and/or detailed information, please see the Wisconsin Wildlife Action Plan. The Wildlife Action Plan is meant to be dynamic and will be periodically updated to reflect new information; the next update is planned for 2015.

Only SGCN highly or moderately (H = high association, M = moderate association) associated with specific community types or other habitat types and that have a high or moderate probability of occurring in the ecological landscape are included here (SGCN with a low affinity with a community type or other habitat type and with low probability of being associated with this ecological landscape were excluded). Only community types designated as "Major" or "Important" management opportunities for the ecological landscape are shown.

Great Egret. Photo by Steve Hillebrand, courtesy of U.S. Fish and Wildlife Service.

	MAJOR							IMPORTANT																		
	Dry Cliff	Great Lakes Beach	Great Lakes Dune	Great Lakes Ridge and Swale	Lake Michigan	Warmwater rivers	Warmwater streams	Bedrock Glade	Coolwater streams	Emergent Marsh	Ephemeral Pond	Floodplain Forest	Interdunal Wetland	Moist Cliff	Northern Dry-mesic Forest	Northern Hardwood Swamp	Northern Mesic Forest	Northern Sedge Meadow	Northern Wet Forest	Northern Wet-mesic Forest	Shrub Carr	Southern Dry-mesic Forest	Southern Mesic Forest	Southern Sedge Meadow	Submergent Marsh	Surrogate Grasslands
Species That Are Significantly Associated with the Central Lake Michigan Coastal Ecological Landscape																										
MAMMALS																										
None																										
BIRDS[a]																										
American Woodcock																M	M				H					
Black Tern										H								M							M	
Black-billed Cuckoo				M								M					M				H					
Blue-winged Teal										H		M						M						M	M	M
Bobolink																		H						M		H
Brown Thrasher				M																						M
Cerulean Warbler												H										H	M			
Common Tern		H			H					M																
Dickcissel																										H
Dunlin		H				M				M																
Eastern Meadowlark																								M		H
Field Sparrow																										M
Forster›s Tern										H															M	
Great Egret						M				H		M													M	
Horned Grebe					H																					
Hudsonian Godwit										H																
Least Flycatcher				M								M			M	M	H									
Lesser Scaup						M																			H	
Northern Harrier																		H						M		H
Osprey						H																				
Peregrine Falcon	H																									

Continued on next page

Appendix 8.E, *continued.*

	MAJOR							IMPORTANT																		
	Dry Cliff	Great Lakes Beach	Great Lakes Dune	Great Lakes Ridge and Swale	Lake Michigan	Warmwater rivers	Warmwater streams	Bedrock Glade	Coolwater streams	Emergent Marsh	Ephemeral Pond	Floodplain Forest	Interdunal Wetland	Moist Cliff	Northern Dry-mesic Forest	Northern Hardwood Swamp	Northern Mesic Forest	Northern Sedge Meadow	Northern Wet Forest	Northern Wet-mesic Forest	Shrub Carr	Southern Dry-mesic Forest	Southern Mesic Forest	Southern Sedge Meadow	Submergent Marsh	Surrogate Grasslands
Prothonotary Warbler												H														
Red-headed Woodpecker												M										M				
Short-billed Dowitcher										H																
Upland Sandpiper																										H
Veery				M								M			M	H	M		M		H	M	M			
Whimbrel		H								M																
Willow Flycatcher																					H			M		M
Wood Thrush				M								M					M					H	H			
HERPTILES																										
Four-toed salamander				H					M	H	H	H				M	H	M	M	H	H		H	M		
Mudpuppy					H	H																				
Northern ribbon snake																					M					
FISH																										
Lake sturgeon					H	H																				
Species That Are Moderately Associated with the Central Lake Michigan Coastal Landscape																										
MAMMALS																										
Eastern red bat						M	M		H	M	H	M			M	M	M	M	M	M	M	M	M	M	M	
Hoary bat						M	M		H	M	H	M			M	M	M	M	M	M	M			M	M	
Northern long-eared bat						M	M		H	M	H	M			M	M	M	M			M	M	M	M	M	
Silver-haired bat						M	M		H	M	H	M			M	M	M	M	M	M	M			M	M	
BIRDS																										
Acadian Flycatcher												M										H	H			
American Bittern										H								H						M		
American Golden Plover										M																M
Bald Eagle					M	H																			M	
Black-throated Blue Warbler															M		H									
Blue-winged Warbler								M				M									M	M	M			
Buff-breasted Sandpiper										M																M
Canada Warbler				H											M	H	M		M	H						
Canvasback						H																			H	
Caspian Tern		H			H																					
Golden-winged Warbler															M	M	M		M		H					
Grasshopper Sparrow																										H
Henslow's Sparrow																										H
Hooded Warbler																						H	H			

Continued on next page

Appendix 8.E, *continued.*

Blandings turtle.
Photo courtesy of U.S. Fish and Wildlife Service.

	MAJOR							IMPORTANT																		
	Dry Cliff	Great Lakes Beach	Great Lakes Dune	Great Lakes Ridge and Swale	Lake Michigan	Warmwater rivers	Warmwater streams	Bedrock Glade	Coolwater streams	Emergent Marsh	Ephemeral Pond	Floodplain Forest	Interdunal Wetland	Moist Cliff	Northern Dry-mesic Forest	Northern Hardwood Swamp	Northern Mesic Forest	Northern Sedge Meadow	Northern Wet Forest	Northern Wet-mesic Forest	Shrub Carr	Southern Dry-mesic Forest	Southern Mesic Forest	Southern Sedge Meadow	Submergent Marsh	Surrogate Grasslands
King Rail										H														M		
Loggerhead Shrike																										H
Marbled Godwit										H																M
Piping Plover		H	H																							
Rusty Blackbird				M						M	M	H									M					
Short-eared Owl																		M			M			M		H
Snowy Egret										H															M	
Solitary Sandpiper				M			M		M	H	H	H	M													
Western Meadowlark																										H
Whip-poor-will								M							M							H				
Wilson›s Phalarope										H								H							M	
Yellow-billed Cuckoo												H									M	M	M			
Yellow-crowned Night-Heron						M				M	H	H									M				M	
HERPTILES																										
Blanding's turtle						M	M		M	H	H	M						M			M	M	M	M	H	
Butler's garter snake										H		M						H			H			H		
Pickerel frog						H	H		H	H	H	M					M	H	M	M	M		M	H	H	
Wood turtle						H	H		H		M	H				M	H	M	M	M	H		M	M	H	
FISH																										
Banded killifish					H																					
Greater redhorse					M	M	H																			
Redside dace							M		M																	
River redhorse						M																				
Shoal chub (speckled chub)						H																				
Western sand darter						M																				

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologists Union.

Appendix 8.F. *Natural communities[a] for which there are management opportunities in the Central Lake Michigan Coastal Ecological Landscape.*

Major opportunity[b]	Important opportunity[c]	Present[d]
Alvar	Northern Dry-Mesic Forest	Southern Hardwood Swamp
Dry Cliff (Curtis' Exposed Cliff)	Northern Mesic Forest	
Great Lakes Dune	Northern Wet-mesic Forest	Cedar Glade
Great Lakes Beach	Northern Wet Forest	
Great Lakes Ridge and Swale	Northern Hardwood Swamp	Alder Thicket
		Bog Relict
Floodplain Forest	Southern Dry-Mesic Forest	
	Southern Mesic Forest	Open Bog
Lake Michigan		Wild Rice Marsh
Warmwater River	Shrub-carr	
Warmwater Stream		Coldwater Stream
	Northern Sedge Meadow	Impoundment/Reservoir
	Southern Sedge Meadow	Inland Lake
	Surrogate Grasslands	
	Emergent Marsh	
	Submergent Marsh	
	Interdunal Wetland	
	Ephemeral Pond	
	Clay Seepage Bluff	
	Bedrock Glade	
	Moist Cliff (Curtis' Shaded Cliff)	
	Coolwater Stream	

[a]See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for definitions of natural community types. Also see Appendix E, "Opportunities for Sustaining Natural Communities in Each Ecological Landscape" in Part 3, "Supporting Materials," for an explanation on how the information in this table can be used.

[b]Major opportunity – Relatively abundant, represented by multiple significant occurrences, or ecological landscape is appropriate for major restoration activities.

[c]Important opportunity – Less abundant but represented by one to several significant occurrences or type is restricted to one or a few ecological landscapes.

[d]Present – Uncommon or rare, with no good occurrences documented. Better opportunities are known to exist in other ecological landscapes, or opportunities have not been adequately evaluated.

Appendix 8.G. *Public conservation lands in the Central Lake Michigan Coastal Ecological Landscape, 2005.*

Property name	Size (acres)[a]
STATE	
Brillion State Wildlife Area	4,835
C.D. (Buzz) Besadny State Fish and Wildlife Area	2,340
Collins Marsh State Wildlife Area	4,290
Deer Creek State Wildlife Area	1,490
Green Bay West Shores State Wildlife Area[b]	1,410
Harrington Beach State Park	610
Holland State Wildlife Area	530
Kohler-Andrae State Park	920
Killsnake State Wildlife Area	5,940
Mack State Wildlife Area	1,375
Maine State Wildlife Area	675
Navarino State Wildlife Area[b]	14,240
Outagamie State Wildlife Area	950
Point Beach State Forest	2,860
Rat River State Wildlife Area[b]	100
Wolf River Bottoms State Wildlife Area	3,070
Miscellaneous Lands[c]	3,470
FEDERAL	
Waterfowl Production Areas	695
COUNTY FOREST[d]	
None	
TOTAL	**49,800**

Source: *Wisconsin Land Legacy Report* (WDNR 2006b).

[a]Actual acres owned in this ecological landscape.

[b]This property also falls within adjacent ecological landscape(s).

[c]Includes public access sites, fish hatcheries, fire towers, streambank and nonpoint easements, lands acquired under statewide wildlife, fishery, forestry, and natural area programs, Board of Commissioners of Public Lands holdings, small properties under 100 acres, and properties with fewer than 100 acres within this ecological landscape.

[d]Locations and sizes of county-owned parcels enrolled in the Forest Crop Law program are presented here. Information on locations and sizes of other county and local parks in this ecological landscape is not readily available and is not included here, except for some very large properties.

Appendix 8.H. *Land Legacy places in the Central Lake Michigan Coastal Ecological Landscape and their ecological and recreational significance.*

The *Wisconsin Land Legacy Report* (WDNR 2006b) identified 17 places in the Central Lake Michigan Coastal Ecological Landscape that merit conservation action based upon a combination of ecological significance and recreational potential.

Map Code	Place name	Size	Protection initiated	Protection remaining	Conservation significance[a]	Recreation potential[b]
CS	Colonial Waterbird Nesting Islands	Small	Substantial	Limited	xxx	x
DP	Door Peninsula Hardwood Swamps	Medium	Limited	Moderate	xxx	x
DC	Duck Creek and Burma Swamp	Small	Limited	Moderate	x	xx
FP	Fischer Creek, Point Creek and Cleveland Swamp	Small	Moderate	Moderate	xx	xxx
KG	Kewaunee River and Grasslands	Medium	Moderate	Moderate	xxx	xxxx
KA	Kohler-Andrae Dunes	Small	Substantial	Limited	xxxx	xxxx
LB	Lower Wolf River Bottomlands	Large	Substantial	Moderate	xxxxx	xxxxx
MB	Manitowoc - Branch River	Large	Moderate	Substantial	xxx	xxxx
MI	Milwaukee River	Large	Moderate	Substantial	xxxx	xxxxx
NE	Niagara Escarpment	Large	Moderate	Substantial	xxxxx	xxxxx
OG	Onion River Grasslands	Small	Limited	Moderate	xx	xxx
PO	Point Au Sable	Small	Substantial	Limited	xx	x
PD	Point Beach and Dunes	Medium	Substantial	Limited	xxxxx	xxxxx
RA	Red Banks Alvar	Small	Moderate	Moderate	xxxx	x
RH	Red Hill Woods - Brussels Grassland	Small	Limited	Moderate	xx	xxx
TW	Twin Rivers	Large	Limited	Moderate	xxx	xxx
WS	West Shore Green Bay Wetlands	Medium	Substantial	Limited	xxx	xx

[a]**Conservation significance.** See the *Wisconsin Land Legacy Report* (WDNR 2006b), p. 43, for detailed discussion.

- xxxxx Possesses outstanding ecological qualities, is large enough to meet the needs of critical components, and/or harbors globally or continentally significant resources. Restoration, if needed, has a high likelihood of success.
- xxxx Possesses excellent ecological qualities, is large enough to meet the needs of most critical components, and/or harbors continentally or Great Lakes regionally significant resources. Restoration has a high likelihood of success.
- xxx Possesses very good ecological qualities, is large enough to meet the needs of some critical components, and/or harbors statewide significant resources. Restoration will typically be important and has a good likelihood of success.
- xx Possesses good ecological qualities, may be large enough to meet the needs of some critical components, and/or harbors statewide or ecological landscape significant resources. Restoration is likely needed and has a good chance of success.
- x Possesses good to average ecological qualities, may be large enough to meet the needs of some critical components, and/or harbors ecological landscape significant resources. Restoration is needed and has a reasonable chance of success.

[b]**Recreation potential.** See the *Wisconsin Land Legacy Report*, p. 43, for detailed discussion.

- xxxxx Outstanding recreation potential, could offer a wide variety of land and water-based recreation opportunities, could meet many current and future recreation needs, is large enough to accommodate incompatible activities, could link important recreation areas, and/or is close to state's largest population centers.
- xxxx Excellent recreation potential, could offer a wide variety of land and water-based recreation opportunities, could meet several current and future recreation needs, is large enough to accommodate some incompatible activities, could link important recreation areas, and/or is close to large population centers.
- xxx Very good recreation potential, could offer a variety of land and/or water-based recreation opportunities, could meet some current and future recreation needs, may be large enough to accommodate some incompatible activities, could link important recreation areas, and/or is close to mid-sized to large population centers.
- xx Good to moderate recreation potential, could offer some land and/or water-based recreation opportunities, might meet some current and future recreation needs, may not be large enough to accommodate some incompatible activities, could link important recreation areas, and/or is close to mid-sized population centers.
- x Limited recreation potential, could offer a few land and/or water-based recreation opportunities, might meet some current and future recreation needs, is not likely large enough to accommodate some incompatible activities, could link important recreation areas, and/or is close to small population centers.

Appendix 8.I. *Importance of economic sectors (based on the number of jobs) within the Central Lake Michigan Coastal counties compared to the rest of the state.*

Industry	CLMC	CSH	CSP	FT	NCF	NES	NH	NLMC	NWL	NWS	SEGP	SLMC	SWS	SCP	WCR	WP
Agriculture, Fishing & Hunting	0.87	2.14	2.41	2.15	2.15	1.90	0.50	2.71	0.43	1.29	0.76	0.10	4.46	0.87	2.36	2.30
Forest Products & Processing	1.64	0.98	1.83	2.40	3.43	2.20	1.33	1.74	0.41	1.07	0.65	0.32	0.45	1.44	0.96	0.69
Mining	1.08	1.64	0.79	0.79	2.69	3.55	0.91	2.16	0.16	0.34	1.47	0.19	0.62	0.08	0.77	1.21
Utilities	2.44	1.08	0.81	0.39	0.61	0.45	0.58	0.41	1.96	1.76	0.67	0.65	0.81	1.83	1.19	0.51
Construction	1.12	1.02	0.89	0.96	1.14	0.92	2.38	1.08	1.07	1.14	1.08	0.67	0.98	1.13	1.03	1.11
Manufacturing (non-wood)	1.23	1.02	0.74	0.98	0.90	1.37	0.21	1.15	0.49	0.59	1.19	0.87	0.78	0.46	0.77	0.99
Wholesale Trade	0.99	0.63	0.61	0.95	0.62	0.53	0.47	0.60	1.15	0.72	1.16	0.98	0.89	0.76	0.83	0.53
Retail Trade	1.01	1.00	0.99	1.11	1.11	1.00	1.66	1.03	1.30	1.19	1.02	0.80	1.69	1.11	1.11	1.13
Tourism-related	0.99	1.12	0.97	0.86	0.99	1.05	1.51	1.28	1.34	1.41	0.94	1.02	0.78	1.33	1.08	1.12
Transportation & Warehousing	0.95	1.32	2.13	1.40	1.19	1.15	0.80	0.89	3.25	2.15	0.82	0.83	0.74	2.12	1.39	0.99
Information	0.76	0.49	0.69	0.74	0.58	0.68	0.80	0.70	0.38	0.49	1.22	1.11	1.09	0.64	0.62	0.57
Finance & Insurance	1.22	1.31	0.89	0.96	0.56	0.46	0.43	0.48	0.47	0.46	1.04	1.18	0.65	0.45	0.70	0.55
Real Estate, Rental & Leasing	0.84	0.73	0.59	0.60	0.52	0.34	1.37	0.95	0.42	0.50	1.17	1.14	0.47	0.46	0.87	0.66
Pro, Science & Tech Services	0.85	0.53	0.46	0.55	0.41	0.36	0.43	0.45	0.51	0.47	1.04	1.51	0.49	0.47	0.63	0.81
Management	0.80	0.26	0.63	0.54	0.37	0.21	0.17	0.24	0.65	0.47	0.94	1.62	0.08	0.64	0.87	0.45
Admin, Support, Waste, & Remediation	0.99	0.42	0.43	0.46	0.34	0.23	0.61	0.34	0.61	0.43	0.92	1.64	0.58	0.51	0.70	0.63
Private Education	0.86	0.68	0.39	0.42	0.86	0.72	0.87	0.55	0.08	0.12	0.80	1.94	0.09	1.53	0.68	0.55
Health Care & Social Services	0.85	0.88	1.27	1.04	0.82	0.90	0.87	0.84	0.96	0.91	0.83	1.32	0.84	0.99	1.09	0.94
Other Services	1.08	1.32	1.10	1.05	1.10	1.13	1.25	1.19	1.36	1.09	1.06	0.84	1.14	1.13	0.91	1.29
Government	0.78	1.09	1.11	1.03	1.26	1.36	1.08	1.03	1.36	1.54	1.04	0.89	1.15	1.50	1.14	1.21

Source: Based on an economic base analysis using location quotients (Quintero 2007). Definitions of economic sectors can be found at the U.S. Census Bureau's North American Industry Classification System web page (USCB 2013).

Appendix 8.J. *Scientific names of species mentioned in the text.*

Common name	Scientific name
Acadian Flycatcher[a]	*Empidonax virescens*
Alder Flycatcher	*Empidonax alnorum*
Alewife	*Alosa pseudoharengus*
American basswood	*Tilia americana*
American beaver	*Castor canandensis*
American beech	*Fagus grandifolia*
American Bittern	*Botaurus lentiginosus*
American black bear	*Ursus americanus*
American elm	*Ulmus americana*
American mink	*Neovison vison*
American sea-rocket	*Cakile lacustris*
American White Pelican	*Pelecanus erythrorhynchos*
Amphipod	*Diporeia hoyi*
Annosum root rot fungus	*Heterobasidion annosum*
Arrowheads	Sagittaria spp.
Ashes	*Fraxinus* spp.
Asian longhorned beetle	*Anoplophora glabripennis*
Aspens	*Populus* spp.
Aspen heart rot fungus	*Phellinus tremulae*
Aspen hypoxylon canker fungus	*Hypoxylon mammatum*
Autumn olive	*Elaeagnus umbellata*
Bald Eagle	*Haliaeetus leucocephalus*
Balsam fir	*Abies balsamea*
Barn Owl	*Tyto alba*
Beech bark disease fungal species	*Nectria galligena, Nectria coccinea* var. *faginata*
Beech scale insect	*Cryptococcus fagisuga*
Bird's-foot trefoil	*Lotus corniculata*
Black ash	*Fraxinus nigra*
Black bullhead	*Ameiurus melas*
Black cherry	*Prunus serotina*
Black crappie	*Pomoxis nigromaculatus*
Black Duck	*Anas rubripes*
Black locust	*Robinia pseudoacacia*
Black Scoter	*Melanitta americana*
Black spruce	*Picea mariana*
Black striate land snail	*Striatura ferrea*
Black-billed Cuckoo	*Coccyzus erythropthalmus*
Black-crowned Night-Heron	*Nycticorax nycticorax*
Blanding's turtle	*Emydoidea blandingii*
Bloater	*Coregonus hoyi*
Bluegill	*Lepomis macrochirus*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Blue-winged Teal	*Anas discors*
Bobolink	*Dolichonyx oryzivorus*
Bronze birch borer	*Agrilus anxius*
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutta*
Buckhorn	*Tritogonia verrucosa*
Buckthorns	*Rhamnus* spp.
Buffaloberry	*Shepherdia canadensis*
Bufflehead	*Bucephala albeola*
Bulrushes	*Schoenoplectus* spp., *Scirpus* spp.
Bur oak	*Quercus macrocarpa*
Bur-reeds	*Sparganium* spp.
Butler's garter snake	*Thamnophis butleri*

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Appendix 8.J, *continued.*

Common name	Scientific name
Canada Goose	*Branta canadensis*
Caspian Tern	*Hydroprogne caspia,* listed as *Sterna caspia* on the Wisconsin Natural Heritage Working List
Cat-tails	*Typha* spp.
Cerulean Warbler	*Setophaga cerulea,* listed as *Dendroica cerulea* on the Wisconsin Natural Heritage Working List
Cherrystone drop land snail	*Hendersonia occulta*
Chinook salmon	*Oncorhynchus tschawytscha*
Christmas fern	*Polystichum acrostichoides*
Ciscoes	*Coregonus* spp.
Clustered broomrape	*Orobanche fasciculata*
Coho salmon	*Oncorhynchus kisutch*
Coliform bacteria	*Escherichia coli*
Common buckthorn	*Rhamnus cathartica*
Common carp	*Cyprinus carpio*
Common Goldeneye	*Bucephala clangula*
Common Loon	*Gavia immer*
Common Merganser	*Mergus merganser*
Common reed	*Phragmites australis*
Common Tern	*Sterna hirundo*
Crown vetch	*Coronilla varia*
Curly pondweed	*Potamogeton crispus*
Cut-leaved teasel	*Dipsacus laciniatus*
Dame's rocket	*Hesperis matronalis*
Deepwater cisco	*Coregonus johannae*
Dentate supercoil land snail	*Paravitrea multidentata*
Diplodia pine blight fungus	*Diplodia pinea*
Double-crested Coromant	*Phalacrocorax auritus*
Dune thistle (Pitcher's thistle)	*Cirsium pitcheri*
Dutch elm disease fungus	*Ophiostoma ulmi*
Dwarf lake iris	*Iris lacustris*
Earthworms	Family Lumbricidae
Eastern cottonwood	*Populus deltoides*
Eastern hemlock	*Tsuga canadensis*
Eastern red bat	*Lasiurus borealis*
Eastern red cedar	*Juniperus virginiana*
Eastern white pine	*Pinus strobus*
Elktoe	*Alasmidonta marginata*
Ellipse	*Venustaconcha ellipsiformis*
Elms	*Ulmus* spp.
Emerald ash borer	*Agrilus planipennis*
Emerald shiners	*Notropis atherinoides*
Eurasian honeysuckles	*Lonicera tatarica, Lonicera morrowii,* and *Lonicera* x *bella*
Eurasian water-milfoil	*Myriophyllum spicatum*
European marsh thistle	*Cirsium palustre*
Filamentous algae (green)	*Cladophora* spp.
Foamflower	*Tiarella cordifolia*
Forest tent caterpillar	*Malacosoma disstria*
Forster's Tern	*Sterna forsteri*
Four-toed salamander	*Hemidactylium scutatum*
Garlic mustard	*Alliaria petiolata*
Giant pinedrops	*Pterospora andromedea*
Gizzard shad	*Dorosoma cepedianum*
Glaucous Gull	*Larus hyperboreus*
Glossy buckthorn	*Rhamnus frangula*

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Appendix 8.J, *continued.*

Common name	Scientific name
Golden-crowned Kinglet	*Regulus satrapa*
Gray Partridge	*Perdix perdix*
Gray wolf	*Canis lupus*
Great Black-backed Gull	*Larus marinus*
Great Egret	*Ardea alba*
Greater redhorse	*Moxostoma valenciennesi*
Greater Scaup	*Aythya marila*
Green ash	*Fraxinus pennsylvanica*
Gypsy moth	*Lymantria dispar*
Handsome sedge	*Carex formosa*
Harbinger-of-spring	*Erigenia bulbosa*
Harlequin Duck	*Histrionicus histrionicus*
Henslow's Sparrow	*Ammodramus henslowii*
Herring Gull	*Larus argentatus*
Hine's emerald	*Somatochlora hineana*
Hooded Warbler	*Setophaga citrina,* listed as *Wilsonia citrina* on the Wisconsin Natural Heritage Working List
Horned Grebe	*Podiceps auritus*
Hybrid cat-tail	*Typha x glauca*
Iceland Gull	*Larus glaucoides*
Iowa Pleistocene vertigo land snail	*Vertigo iowaensis*
Ivory Gull	*Pagophila eburnea*
Japanese barberry	*Berberis thunbergii*
Karner blue butterfly	*Lycaeides melissa samuelis*
King Eider	*Somateria spectabilis*
Kiyi	*Coregonus kiyi*
Lake herring	*Coregonus artedii*
Lake sturgeon	*Acipenser fulvescens*
Lake trout	*Salvelinus namaycush*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Laurentian bladder fern	*Cystopteris laurentiana*
Least Flycatcher	*Empidonax minimus*
Lesser Black-backed Gull	*Larus fuscus*
Lesser Scaup	*Aythya affinis*
Lilacs	*Syringa* spp.
Loggerhead Shrike	*Lanius ludovicianus*
Longear sunfish	*Lepomis megalotis*
Long-spur violet	*Viola rostrata*
Long-tailed Duck	*Clangula hyemalis*
Lyme grass	*Leymus arenarius*
Mallard	*Anas platyrhynchos*
Maples	*Acer* spp.
Marram grass	*Ammophila breviligulata*
Midwest Pleistocene vertigo land snail	*Vertigo hubrichti*
Mink frog	*Lithobates septentrionalis*
Monkeyface	*Quadrula metanevra*
Mourning Warbler	*Geothlypis philadelphia*
Multiflora rose	*Rosa multiflora*
Muskellunge	*Esox masquinongy*
Narrow-leaved cat-tail	*Typha angustifolia*
Nashville Warbler	*Oreothlypis ruficapilla*
North American river otter	*Lontra canadensis*
Northern cricket frog	*Acris crepitans*
Northern Harrier	*Circus cyaneus*

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Appendix 8.J, *continued.*

Common name	Scientific name
Northern pike	Esox lucius
Northern red oak	*Quercus rubra*
Northern Waterthrush	*Parkesia noveboracensis*
Northern white-cedar	*Thuja occidentalis*
Norway maple	*Acer platanoides*
Oaks	*Quercus* spp.
Osprey	*Pandion haliaetus*
Passenger Pigeon	*Ectopistes migratorius*
Peregrine Falcon	*Falco peregrinus*
Pine blight fungus	*Diplodia pinea*
Pine sawfly	*Neodiprion* spp., *Diprion* spp.
Piping Plover	*Charadrius melodus*
Prairie dunewort	*Botrychium campestre*
Predacious diving beetles	*Agabetes acuductus, Lioporeus triangularis,* and *Matus bicarinatus*
Privets	*Ligustrum* spp.
Prothonotary Warbler	*Protonotaria citrea*
Pugnose minnow	*Opsopoeodus emiliae*
Purple loosestrife	*Lythrum salicaria*
Pygmy snaketail	*Ophiogomphus howei*
Quagga mussel	*Dreissena bugensis*
Quaking aspen	*Populus tremuloides*
Rainbow smelt	*Osmerus mordax*
Rainbow trout	*Oncorhynchus mykiss*
Red maple	*Acer rubrum*
Red-breasted Merganser	*Mergus serrator*
Red-breasted Nuthatch	*Sitta canadensis*
Redfin shiner	*Lythrurus umbratilis*
Red pine pocket mortality fungi	*Leptographium terrebrantis* and *L. procerum*
Red-shouldered Hawk	*Buteo lineatus*
Red-throated Loon	*Gavia stellata*
Reed canary grass	*Phalaris arundinacea*
Ringed-bill Gull	*Larus delawarensis*
Ring-necked Pheasant	*Phasianus colchicus*
River redhorse	*Moxostoma carinatum*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Round goby	*Neogobius melanostomus*
Round pigtoe	*Pleurobema sintoxia*
Russian olive	*Eleagnus angustifolia*
Rusty crayfish	*Orconectes rusticus*
Sandhill Crane	*Grus canadensis*
Salamander mussel	*Simpsonaias ambigua*
Sand dune willow	*Salix cordata*
Sand reedgrass	*Calamovilfa longifolia* var. *magna*
Sea lamprey	*Petromyzon marinus*
Seaside spurge	*Euphorbia polygonifolia*
Sedges	*Carex* spp.
Sedge Wren	*Cistothorus platensis*
Shoal (speckled) chub	*Macrhybopsis hyostoma*, formerly known as *M. aestivalis*
Shortjaw cisco	*Coregonus zenithicus*
Shortnose cisco	*Coregonus reighardi*
Siberian elm	*Ulmus pumila*
Silver maple	*Acer saccharinum*
Slimy sculpin	*Cottus cognatus*

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Appendix 8.J, *continued.*

Common name	Scientific name
Slippershell	*Alasmidonta viridis*
Smallmouth bass	*Micropteris dolomieu*
Smelt	Family Osmeridae
Snow trillium	*Trillium nivale*
Snowy Egret	*Egretta thula*
Snuffbox	*Epioblasma triquetra*
Spiny water flea	*Bythotrephes cederstroemi*
Striped shiner	*Luxilus chrysocephalus*
Suckers	Family Catostomidae
Sugar maple	*Acer saccharum*
Surf Scoter	*Melanitta perspicillata*
Swamp white oak	*Quercus bicolor*
Sweet-scented Indian-plantain	*Cacalia suaveolens*
Tamarack	*Larix laricina*
Thayer's Gull	*Larus thayeri*
Thickspike	*Elymus lanceolatus* ssp. *psammophilus*
Threespine stickleback	*Gasterosteus aculaeatus*
Upland Sandpiper	*Bartramia longicauda*
Walleye	*Sander vitreus*
Western sand darter	*Ammocrypta clara*
White ash	*Fraxinus americana*
White bass	*Morone chrysops*
White birch	*Betula papyrifera*
White-breasted Nuthatch	*Sitta carolinensis*
White oak	*Quercus alba*
White perch	*Morone americana*
White pine blister rust	*Cronartium ribicola*
White spruce	*Picea glauca*
White sucker	*Catostomus commersonii*
White sweet clover	*Melilotus alba*
White-tailed deer	*Odocoileus virginianus*
White-throated Sparrow	*Zonotrichia albicollis*
White-winged Scoter	*Melanitta fusca*
Wild parsnip	*Pastinaca sativa*
Wild rice	*Zizania* spp.
Wild Turkey	*Meleagris gallopavo*
Winter Wren	*Troglodytes hiemalis*
Wood Duck	*Aix sponsa*
Wood turtle	*Glyptemys insculpta*
Yellow perch	*Perca flavescens*
Yellow birch	*Betula alleghaniensis*
Yellow Rail	*Coturnicops noveboracensis*
Yellow sweet clover	*Melilotus officinalis*
Yellow-billed Cuckoo	*Coccyzus americanus*
Zebra mussel	*Dreissena polymorpha*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologists Union.

Appendix 8.K. *Maps of important physical, ecological, and aquatic features within the Central Lake Michigan Coastal Ecological Landscape.*

- Vegetation of the Central Lake Michigan Coastal Ecological Landscape in the Mid-1800s
- Land Cover of the Central Lake Michigan Coastal Ecological Landscape in the Mid-1800s
- Landtype Associations of the Central Lake Michigan Coastal Ecological Landscape
- Public Land Ownership, Easements, and Private land enrolled in the Forest Tax Programs in the Central Lake Michigan Coastal
  Ecological Landscape
- Ecologically Significant Places of the Central Lake Michigan Coastal Ecological Landscape
- Exceptional and Outstanding Resource Waters and 303(d) Degraded Waters of the Central Lake Michigan Coastal Ecological Landscape
- Dams of the Central Lake Michigan Coastal Ecological Landscape
- WISCLAND Land Cover (1992) of the Central Lake Michigan Coastal Ecological Landscape
- Soil Regions of the Central Lake Michigan Coastal Ecological Landscape
- Relative Tree Density of the Central Lake Michigan Coastal Ecological Landscape in the Mid-1800s
- Population Density, Cities, and Transportation of the Central Lake Michigan Coastal Ecological Landscape

Note: *Go to* ***http://dnr.wi.gov/topic/landscapes/index.asp?mode=detail&Landscape=17*** *and click the "maps" tab.*

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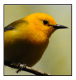

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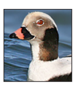

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